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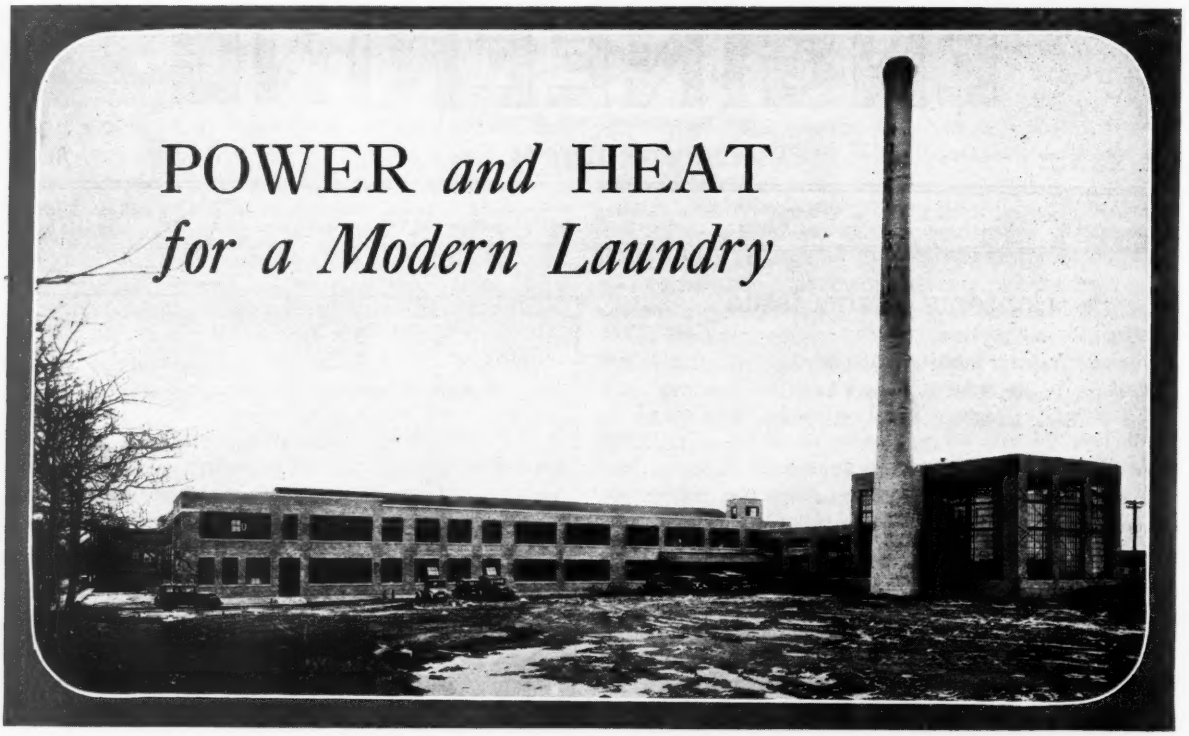
Beckoning of the Vacation Goddess

WHAT BOY RAISED on the plains has not run in a circle at least three times around a screech owl sitting on the mound at the entrance to a prairie dog hole in an endeavor to have the owl twist his own head off? Or could anybody resist the temptation to watch the funnel of a tornado, at a safe distance, of course? The eagle and hawk descend upon their prey in spirals, four-footed prairie and forest animals turn in a circle several times before retiring, birds' nests are round, water flowing naturally seems to avoid a straight course but is fond of making whirlpools—all nature loves the curve, the circle and the spiral.

Habit is so strong that even plant life catches the spirit of the animals and elements and we have at the top of this column a photograph of nature's monument erected beside a winding path up Mt. Henry in Glacier National Park. Nature alone holds the secret as to how this goddess of the mountain path was erected; your guess is as good as anybody's but we suspect that the currents of air on the mountain are quite definitely controlled. Well, anyway, if you will turn to page 706 you will find one way of making the air currents give up their secrets.

POWER *and* HEAT *for a Modern Laundry*



LARGE QUANTITY AND GOOD QUALITY OF WATER AND TEMPERATURE CONTROL ARE DOMINANT FEATURES OF POWER PLANT OF THE MOREY-LA RUE LAUNDRY, ELIZABETH, N. J.

UNIQUE POWER AND HEATING requirements are found in modern large laundry practice and although, because of their limitations, such power plants cannot use all of the refinements possible in a modern central station, advantage is taken, however, of certain permissible practices which have proved themselves of worth in central station practice and to these are added other refinements that are distinctive in character to laundry service.

Especially is this careful attention to refinement exercised by organizations which control a group of plants as is the case with the Morey-La Rue Laundry in which the plant at Elizabeth, N. J., which was started on November 17, 1928, is the most recent and most finely equipped of the four plants owned and operated in different cities by the parent organization. The Elizabeth plant probably represents the last word in laundry power.

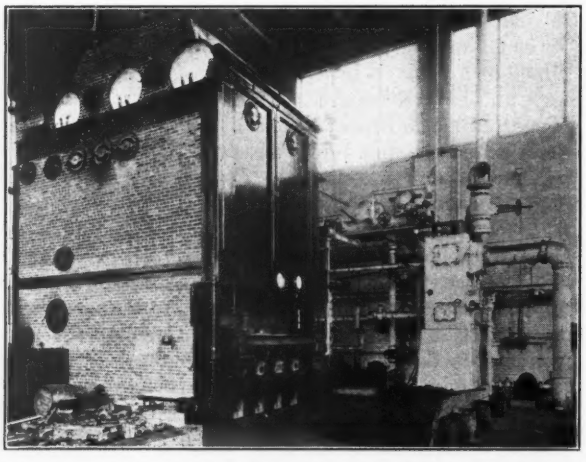


FIG. 1. BOILER ROOM SHOWING FEEDWATER HEATER AND PIPING CONNECTIONS ALONG WHICH THE PUMPING EQUIPMENT IS INSTALLED

LAUNDRY PLANTS HAVE UNIQUE HEATING REQUIREMENTS

Laundry power plants have no place for superheaters or economizers but the heat reclaimer, which transfers what would otherwise be lost heat from waste wash water to make up boiler feedwater, finds a unique place in such plants. High pressures are not required but large capacity for heating water and careful regulation of water temperatures are highly essential expedients. No special condenser is used. All of the steam is condensed in the laundry machines used for drying clothes and is returned by Armstrong traps to the Cochrane feedwater heater.

EXCELLENT OPERATING FACILITIES PROVIDED

Housed in a fine building of Austin design and construction, built of brick and stone and fitted with large steel sash windows which afford excellent ventilation by opening at the top of each sash, exceptional facilities are provided for operation and expansion. The boiler room is 60 ft. wide and the engine room 48 ft. wide: Both have a uniform depth of 50 ft. Cement floors are provided and the walls, which have no wainscoting, are painted with aluminum paint. All of the light comes through windows at the sides which, due to their height

and area, provide ample light. Artificial light is provided by nine 200-w. lights provided with reflectors and suspended from the ceiling in the boiler room and eleven in the turbine room. The laundry plant runs 8½ hr. a day; 47 hr. a week.

One 450-hp. Stirling water-tube boiler is now installed but space is available for two additional units. The boiler is fitted with a Huber overfeed, mechanical stoker. Bituminous non-coking coal which has a heating value of 14,000 B.t.u. per lb. is served to the stoker hopper by hand.

Steam from Stoker Motors Reduces Clinkers

Agitation of the fuel bed is accomplished mechanically and the stoker is mechanically controlled by steam motors as shown in Fig. 1. Exhaust steam coming from the motors is conveyed by pipes to undergrate steam jets located in the rear of the grate for use in disintegrating clinker which might form on the grate surface or fuel bed. The grate surface is 10 ft. wide by 8 ft. 11 in. long, the area, therefore, being slightly over 89 sq. ft. Operating under natural draft conditions with this grate area, a rating of 200 per cent may be obtained continuously.

Operation of the steam motors and the dampers is controlled by a Collins partial stroke automatic draft and pressure regulator which is water operated and which maintains a very uniform steam pressure as will be seen at D, Fig. 6. Almost exact balance is maintained by means of a weight rolling on a balance beam, whose position is automatically adjusted to the steam pressure and opens or closes the draft correspondingly as required. The stack, which is built of brick, is 6 ft. diameter at the bottom and 150 ft. high. The blowoff tank, which is 3 ft. in diameter and 6 ft. high, is located underground and outside of the building.

Furnace Construction Promotes Good Combustion

Among the unique features of Morey-La Rue plant is the boiler furnace construction which is illustrated in Fig. 3. This system consists essentially of a secondary over-fire air arch, a special 13½-in. silicon-carbide coking shelf supported by special silicon-carbide

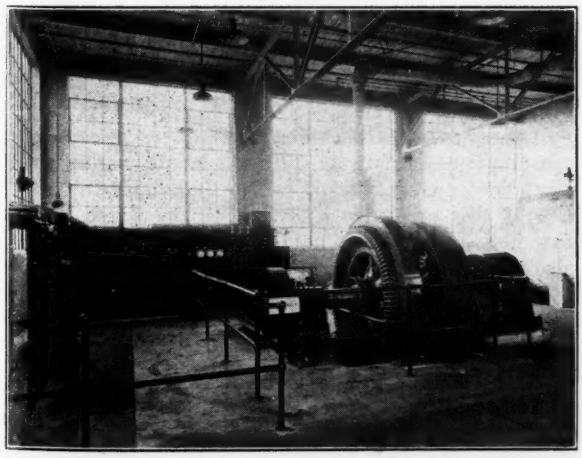


FIG. 2. ENGINE ROOM SHOWING HOT-WATER HEATER AND SWITCHBOARDS, THE ONE AT THE EXTREME LEFT BEING THE LAUNDRY MACHINERY AUTOMATIC SWITCHBOARD

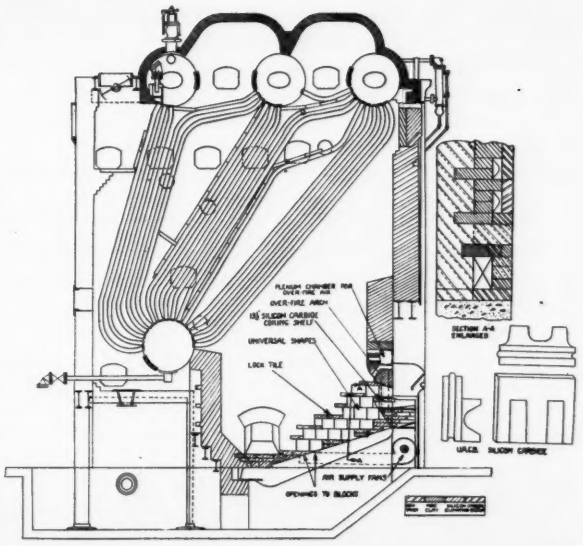


FIG. 3. CROSS SECTION OF BOILER SHOWING FURNACE CONSTRUCTION

skew-brick, faced piers and a fire-clay tile so designed as to permit radiant heat to reach the bottom of the coking shelf tile. The shelf and arch are so designed as to take advantage of all the radiant heat possible in order to promote rapid distillation of the volatile gases which are burned a little later when they mix with preheated secondary air flowing in through holes in the arch. The jet action of this incoming air sets up a turbulence which causes the mixture, and hence the combustion, to be improved.

The long travel of the fuel on the coking shelf, which is from 50 to 100 per cent longer than is usual with overfeed stokers, insures a more complete coking of the coal before it drops off onto the grate surface.

Overfire Air Is Preheated

Preheated overfire air is obtained by using the side walls of the furnace as air preheaters. Air cooled silicon-carbide block was used for the furnace lining because of its high heat conductivity and because of the efficient cooling of the block due to the increased scrubbing action possible with this type of block, the cooling air scrubbing a greater area on the back of the block and projecting lugs than is presented to the fire.

From tests made on this arrangement supplemented by calculations, the requisite amount of secondary air for most efficient operation for the given volatile content in the coal, has been determined. Operation based upon this determination has resulted in the remarkably clean furnace wall shown in Fig. 4, which is a photograph made of the interior of the furnace after three months continuous service. The perfect condition of the side walls is emphasized by the fact that the numbers stamped on the blocks are still visible on most of them.

Temperatures observed on this arrangement of furnace have been as follows: Fuel burning on shelf, 2540 deg. F.; fuel burning on grates, observed through front door with door open, 2420 deg. and on the rear part of the stoker, 2750 deg. The stack temperature averages about 470 deg. and the percentage of CO_2, about 13.4. In an observation made on February 3, while running

at 150 per cent rating, the average CO_2 was found to be 14.5 per cent, while the temperature of flue gas was only 420 deg. Under these conditions, the overall efficiency was 76 per cent. The combination of arch and coking shelf shown, which was designed and installed by the Essex Engineering Co., is new and this is the first time a coking shelf of this design has been installed.

Storage Tank Carries Water at Two Levels

City water is used for boiler feed make up. Storage is accomplished in a steel water tank located on a steel tower 100 ft. high, which has a capacity of 150,000 gal. carried in two levels. This is accomplished by connecting two pipe lines to the water tank, one, a 6-in. filling line from the booster pump, acts also as a riser extending in height to the 100,000-gal. line so as to draw its supply from the top of the 50,000-gal. capacity. This

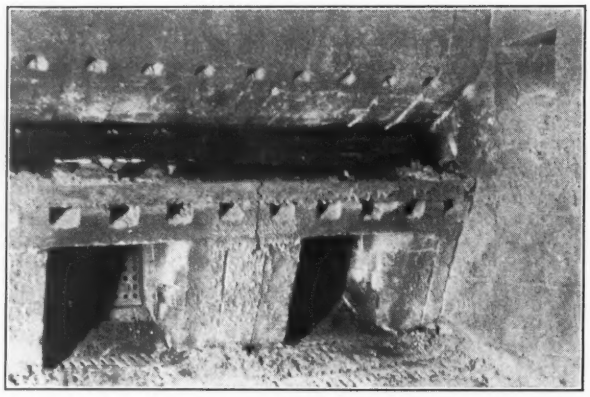


FIG. 4. INTERIOR OF FURNACE SHOWING COMBINATION OF ARCH AND COKING SHELF. PHOTOGRAPH TAKEN AFTER THREE MONTHS' CONTINUANCE OPERATION INDICATES GOOD COMBUSTION CONDITIONS

100,000-gal. capacity is intended for domestic supply. An 8-in. discharge line which supplies the sprinkler system for fire protection, takes its supply from the bottom of the 36-in. riser which is connected to the bottom of the tank. By this arrangement, at least 50,000 gal. of water is reserved for fire protection throughout the entire plant.

Zeolite System Used for Water Softening

Water softening, which is such an important item in laundry practice, is accomplished by a vertical type Paige-Jones double-unit, rapid-rate, zeolite system of the upflow type. The softening units are 84 in. diameter by 108 in. high and are supplied with a steel storage tank 60 in. diameter by 48 in. high, having a capacity of 3500 lb. of salt. Each softening unit has a capacity between reconditionings, of 97,000 gal. of water and will furnish water at the rate of 18,500 gal. per hr., using 328 lb. of salt for the 97,000 gal. of soft water furnished, which is at an approximate rate of one pound of salt for every 300 gal. of water treated. The units may be operated either in parallel or alternating, as desired.

Heat Reclamation Reduces Coal Consumption

Reclamation of heat from waste wash water is accomplished by a Whitlock water preheater which has a rated capacity of 21,000 gal. per hr. Its internal construction consists of a large number of U-shaped, one-inch coils made of heavy gage, seamless copper tubing which connect at one end with a tube sheet or header. Header, tubes and connecting piping are enclosed in a rectangular tank which is located under the engine-room floor. Heat transfer is accomplished by counter current principle and in two stages. Water from the city line enters the preheater at about 50 deg. and is heated by the waste water to from 100 to 110 deg. as will be seen at A in Fig. 6. Water at 100 deg. temperature is used for rinsing purposes in the laundry. Further heating

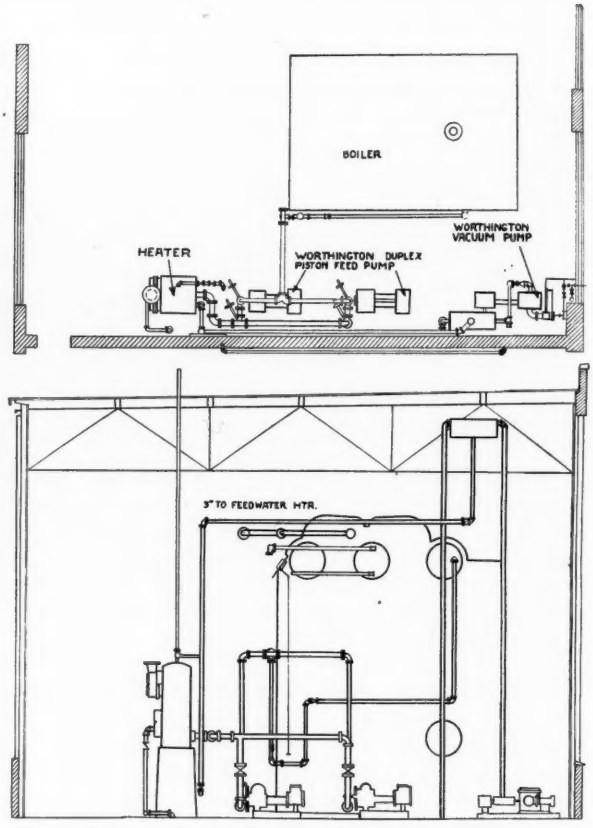


FIG. 5. BOILER FEED MAKE-UP SYSTEM

is applied for the wash water, raising its temperature to from 200 to 230 deg. by passing it through a surface heater which uses the exhaust steam from the engine as heating medium.

Operation with the water preheater reduces the fuel consumption from 20 to 30 per cent depending somewhat on the class of work which the laundry is doing. Use of this preheater also reduces the boiler load so that only one boiler is needed at the present time. It also increases the temperature of the water and permits of a more accurate control of washing conditions.

Thorough Provision Made for Obtaining Records

Other provisions for complete control of operations include the installation of a Brown recording flow meter for water, a Brown steam-flow meter, a Brown recording pyrometer for stack temperature and a Hayes CO_2 recorder. The laundry switchboard shown at the extreme left in Fig. 2 embodies the American panel control in which contacts are made automatically in a manner

similar to that on an automatic telephone switchboard. By this means, motors attached to laundry machinery are braked and then reversed automatically at set intervals. Cutler-Hammer controls are used on this switchboard.

Pumping of hot water is done by a Worthington centrifugal pump which is direct connected to a 5-hp. 150 lb. and a back pressure of 5 lb. This engine is equipped with a floating piston, telescopic type steam valves and auxiliary exhaust ports. The guaranteed water rates in pounds of steam per indicated horsepower at different loads are as follows:

Rated Load	¼	½	¾	Full
Water Rate	21.6	20.2	20.3	21.3

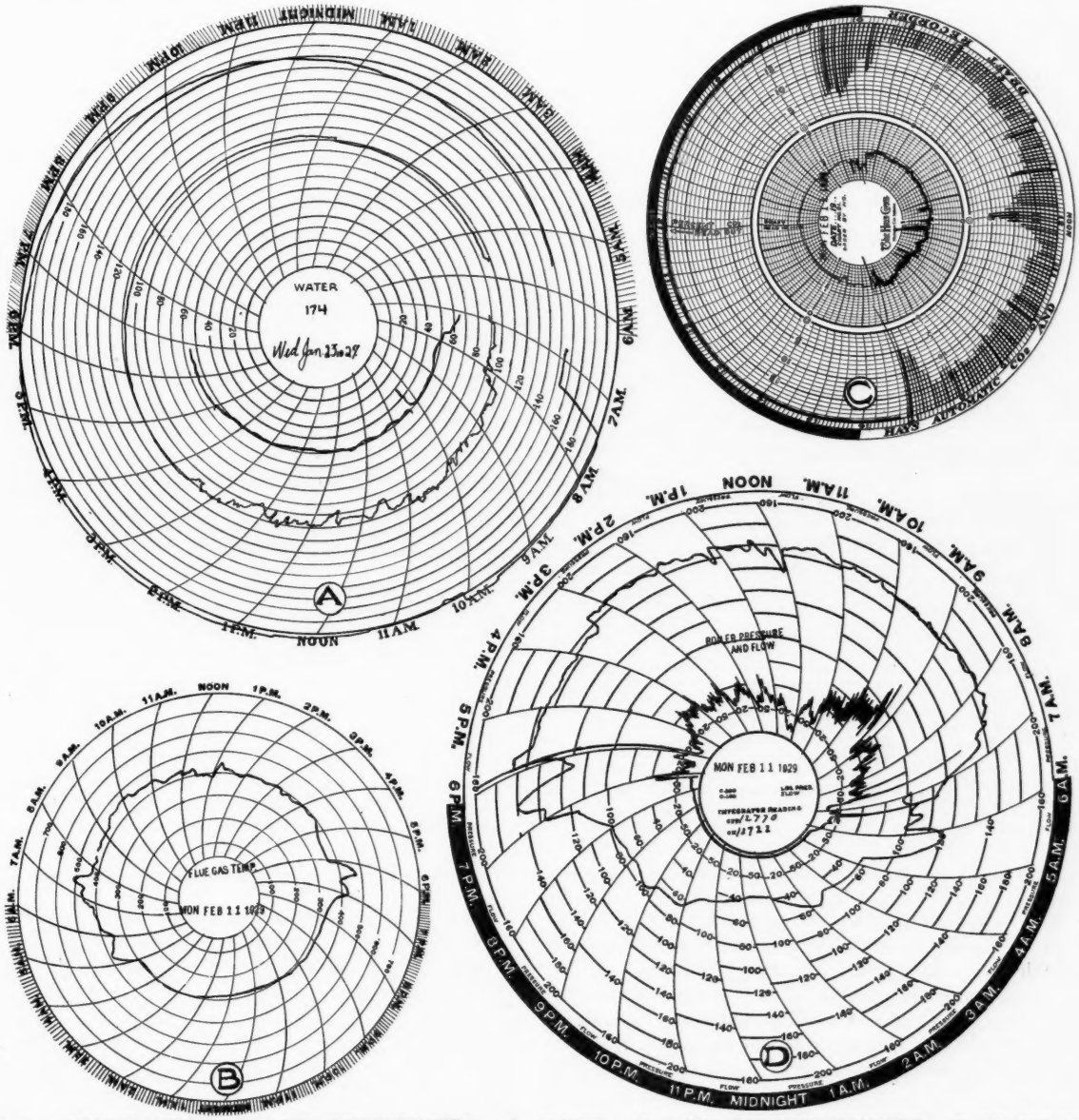


FIG. 6. CHARTS SHOWING PLANT PERFORMANCE: A—WATER. B—FLUE GAS TEMPERATURE. C—DRAFT AND CO_2. D—BOILER PRESSURE AND STEAM FLOW

General Electric induction motor. Two 10 by 6 by 10-in. Worthington steam pumps are used for boiler feeding and an 8 by 10 by 12-in. Worthington steam-operated, vacuum pump takes care of the returns from the heating system.

Electric power for the plant is generated by a 300-kw. alternating current, General Electric, three-phase, 60-cycle generator which is direct connected to a 480-hp., 22½ by 24-in. Universal Unaflow steam engine running at 200 r.p.m. with a steam pressure at the throttle of

Connection is also maintained with public utility service in order that electricity may be purchased for part of the load when desired. In this case, this purchased electricity can be used for lights and for operating the pumps while the engine furnishes power for the laundry machinery.

Voltage regulation in a laundry plant is a very important matter because, without such regulation, great fluctuations result when large laundry machinery is sud-

denly thrown in or out of power. A General Electric voltage regulator provides for this emergency at this plant.

Fire Protection

Besides the provision made in the large water storage already described, a Worthington centrifugal pump having a capacity of 490 g.p.m. against a 150-ft. head is provided for fire purposes. This is direct connected to a 25-hp. General Electric, three-phase, 60-cycle induction motor operating at 3550 r.p.m. This pump starts automatically when the level in the large water tank drops below a fixed point. A Fyre-Freez portable fire-protection apparatus which employs CO_2 gas for extinguishing flames is also provided and automatic fire sprinklers are distributed throughout the plant.

Design and installation of the plant was accomplished by The Austin Co., Engineers and Architects; W. H. Thurber is superintendent of the plant and Theodore Urbanowitz is the chief engineer of the power plant.

Coal comes by barge or train and is handled by monorail buckets to the storage yard or bunkers or by transporter cranes. The cranes also handle ash from the storage bunker to cars or barges. From the coal storage to boiler house, coal is handled by a bridge crane, which also carries a track for the monorail buckets to deliver to storage.

In coal preparation, breakers reduce to 1.2 in. diam. for stokers or to powder for the pulverizers. Bucket and belt elevators serve from breaker to boiler house.

Coal by rail may be dumped into a 500-t. auxiliary storage and carried thence by the transporter crane to main storage or breaker hoppers.

Ash pass by spouts and a hydraulic conveyor to tanks and by the transporter crane to storage bin, cars or barges, with provision for the use of hand trucks in place of the hydraulic conveyor.

Stacks are of steel, of the Prat-venturi, induced-draft design, one to a boiler. Chain grate stokers with forced draft, steel-tube economizers and plate air heaters are installed, the economizers raising feedwater from 185 deg. up to 302 deg. and air heaters delivering at 290 deg.

Instrument equipment is complete to measure pressures and temperatures of feedwater, steam, air and flue gases, also CO_2 and station output.

Four turbine-generator units are installed, with 12,000 kw. most economical load and for 15,000 kw. continuous output, at 50 cycles per second.

Principal Power Power Plant Equipment of Morey-La Rue Laundry

1 Skinner Engine Co., 22½ by 24-in., 480-hp., Universal Unaflow steam engine with floating piston, telescopic type steam valves and auxiliary exhaust ports, operating at 150 lb. steam pressure and 5 lb. back pressure.

1 General Electric Co., 300-kw., 3-phase, 60-cycle, 240-v., alternator, direct connected, to engine and operating at 200 r.p.m.

1 General Electric Co., 12-kw., compound-wound, 125-v., exciter, belted to generator and operating at 750 r.p.m.

1 Babcock and Wilcox Co., 425-hp. Stirling water-tube boiler. Designed to operate at 200 per cent rating under natural draft.
Water heating surface...4238 sq. ft.
Grate area .....89¼ sq. ft.
Furnace volume.....107⅛ cu. ft.
Number of tubes.....330
Diameter of steam drums.....36 in.
Thickness of drum shells...19/32 in.
Type of joints—Tubes have expanded seats in drum shells.

1 Flynn and Emrich Co. Huber, overfeed, full mechanical stoker with steam motor control. Rating: 14 lb. coal per sq. ft. grate surface per hr. with 0.002 in. draft in furnaces and 0.3 in. draft in flue.

1 Whitlock Coil Pipe Co., two-stage water preheater. Rated capacity 21,000 gal. per hr.

1 Paige & Jones Chemical Co. double unit system vertical type zeolite upflow softener. Each softener unit, 84 in. diameter by 108 in. high with steel storage tank 60 in. diameter by 48 in. high and having a capacity of 18,500 gal. water per hr.

2 Worthington Pump and Machinery Corp. centrifugal fire pumps. Capacity, 490 g.p.m. against 150-ft. head operating at 3550 r.p.m. Direct driven by 25-hp. General Electric, 3-phase, 60-cycle induction motor.

1 Worthington Pump and Machinery Corp., 350-g.p.m. centrifugal pump for hot well system. Direct connected to General Electric Co., 5-hp., 3-phase, 60-cycle, induction motor operating at 1740 r.p.m. under 220 v.

2 Worthington Pump and Machinery Corp., 10 by 6 by 10-in. steam, boiler-feed pumps.

1 Worthington Pump and Machinery Corp., 8 by 10 by 12-in. vacuum pump for heating return system.

1 150,000-gal. steel tank, installed by Des Moines Co., Pittsburgh. Elevation 100 ft.

1 Alphons Custodis Chimney Construction Co., brick stack, 6 ft. diameter at base and 150 ft. high.

1 Cochrane Corp. feedwater heater, equipped with multi-ported, atmospheric relief valve. Capacity, 800 hp.

1 Cochrane Corp. surface heater for hot water. Heating surface, 283 sq. ft.

1 Cochrane Corp. 6-in. vertical receiver separator.

1 Swartwout Co. 2-in. S-C feedwater regulator.

2 Ruggles-Klingemann Mfg. Co. Step Action damper regulators; one 2½ in., the other 4 in.

1 Brooke Engineering Co. damper control.

1 Collins Engineering Co. Partial Stroke automatic draft and pressure regulator.

1 Swartwout Co. 10-in. cast-iron exhaust head.

1 Armstrong Machine Works No. 30 steam trap.

1 Crane Co. non-return steam trap.

1 Penberthy Injector Co. No. 2 steam injector.

5 Diamond Power Specialty Corp. valve-in-the-head soot blowers.

1 Everlasting Valve Co. blowoff valve.

1 Foster Engineering Co. 2½-in. reducing valve.

1 Foster Engineering Co. 4-in. reducing valve.

1 Meriam Co. indicating flow meter for hot water.

1 Brown Instrument Co. steam flow meter.

1 Brown Instrument Co. water flow meter.

1 Brown Instrument Co. recording pyrometer.

1 Hayes Corp. CO_2 recorder.

2 Time-O-Stat Controls Co., Absolute Con-Tac-Tor water temperature regulator.

1 Babcock & Wilcox Co. steam gage.

Panel control board for laundry machinery designed by American Laundry Machine Co.

Cutler-Hammer Mfg. Co. control equipment.

Switchboard for generator and electric distribution, designed by General Electric Co. and Austin Co. and installed by Schoonover & Co., Newark, N. J.

1 General Electric Co. voltage regulator.

Automatic fire sprinklers installed by Raisler Sprinkler Equipment Co.

Refractories for furnace. Seaboard Universal Air-Cooled Silicon Carbine blocks.

Furnace construction by Essex Engineering Co.

Ivry, Paris, Power Plant in Service

To supply power to the Metropolitan Underground Railway of Paris, a new station, planned for 130,000 kw. is under construction at Ivry Port on the Seine about 1 mi. above the city of Paris. The first section, 60,000 kw., is now in service.

Operating values are 313 lb. pressure, 707 deg. temperature. Six boilers of 1200 hp. each are stoker fired and two of 1800 hp. each are for pulverized coal, all guaranteed for 85 per cent efficiency. Overload capacity is designed as 42.5 per cent for stokered and 35.5 per cent for powdered coal fired units.

Size alone is not an indication of power plant efficiency. Small plants with modern equipment can be designed to approach closely the results of larger stations.

Boiler Furnace Failures†

THEIR CAUSES AND REMEDIES. BY
A. A. POTTER* AND H. L. SOLBERG**

TO DECREASE the investment in boiler equipment, there has been a continual increase in the size of boilers, stokers and furnaces and a tendency to operate them at higher ratings. Increase in the height of the furnace wall and the higher furnace temperatures brought about by forcing boilers have imposed severe duties upon the firebrick and have greatly increased the cost of furnace maintenance. In fact, for many boilers,

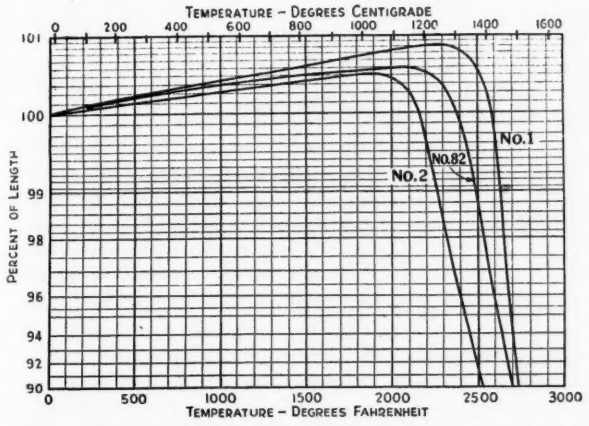


FIG. 1. DEFORMATION OF FIRE BRICK AT 25 LB. PER SQ. IN.

the ability of the brick work to stand up under severe operating conditions is the limiting factor in determining the output obtainable.

Refractory failures are due to: (1) failure of the wall structure; (2) clinker adhesion; (3) spalling and (4) erosion. The first generally arises from poor wall design with respect to loading and support; the other three are caused by poor material, improper design, type of fuel used or conditions of operation.

FAILURE OF WALL STRUCTURE

Failure of the wall structure is never due to the actual fusion of first quality firebrick since such brick will not fuse below 3100 deg. F., a temperature not encountered in boiler furnaces. Firebrick softens, however, under high temperatures and may show plastic deformation under a load of 20 lb. per sq. in. at temperatures of 500 to 1000 deg. F. below the fusion temperature. Figure 1, from a paper on Boiler Furnace Refractories by E. B. Powell before the A. S. M. E., Dec., 1925, shows the results of tests on typical fire brick. Some high walls carry a load of over 40 lb. per sq. in. but the temperature gradient through a brick wall heated on only one side, is quite steep and not over 20 per cent of the thickness of the wall would be exposed to temperatures high enough to cause plastic deformation, if no insulation is used. The use of insulating brick will increase the depth of penetration of high temperatures.

Failure to maintain a vacuum in the furnace is a common cause of firebrick failure. Experiments conducted by R. M. Howe on a special furnace at the Mellon Institute in Pittsburgh indicated that with a furnace temperature of 2440 deg. F., the wall temperature ½ in. from the inner face was 2030 deg. F. with a slight vacuum in the furnace, 2300 deg. F. with 0.05 in. pressure and 2380 deg. F. with 1 in. pressure. As long as a vacuum is maintained in the furnace, some air is drawn through the porous brick and prevents it from overheating. A positive pressure will reverse this process and may cause failure due to plastic deformation of an overheated wall.

CLINKER ADHESION

Clinker adhesion to the walls of a furnace is a common cause of firebrick trouble with coals having an ash

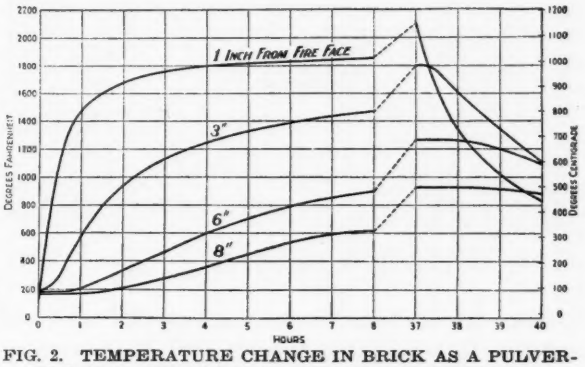


FIG. 2. TEMPERATURE CHANGE IN BRICK AS A PULVERIZED COAL FURNACE IS FIRED UP AND SHUT DOWN

of relatively high fusing temperature. Particles of ash, heated to the softening point in the fuel bed, adhere to the walls and gradually build a hard, strongly-adherent clinker above the grate surface. Finally it becomes necessary to break this off and in so doing brick may be broken out of the wall.

With underfeed stokers, perforated, air-cooled, cast-iron side wall blocks extending to the top of the fuel bed will reduce clinker adhesions. With chain grate and underfeed stokers, square steel boxes, bare tubes or tubes protected by cast iron blocks are installed in the side walls above the grate line and connected into the boiler circulation. Molten ash will solidify on coming into contact with these cold surfaces so that it will not stick to them. Silicon carbide or carborundum brick, to which clinker will not adhere strongly, are often installed in the side walls.

The principal objection to silicon carbide bricks is their cost. Their thermal conductivity is 6 or 8 times that of firebrick so that they are ordinarily made into special shapes which are installed in the side wall with

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*Dean of Engineering, Purdue University.
**Assistant Professor of Mechanical Engineering, Purdue University.

air circulation behind them to keep the face cool and often with holes through which air is injected into the furnace.

Spalling

Spalling is a prolific source of refractory trouble in oil-fired furnaces and is encountered to a lesser degree in furnaces burning the better grades of coal. It is caused by thermal stresses induced by rapid changes in temperature. Figure 2 from Mr. Powell's paper shows the variation in temperature in a brick when a pulverized-coal fired boiler is brought into service and then shut down. The stresses caused by rapid and unequal heating and cooling will cause brick to shear off or spall, parallel with the face of the wall. The tendency of a brick to spall depends partly upon the materials from which it is made and its porosity. A soft burned, open textured brick seems to resist spalling better than

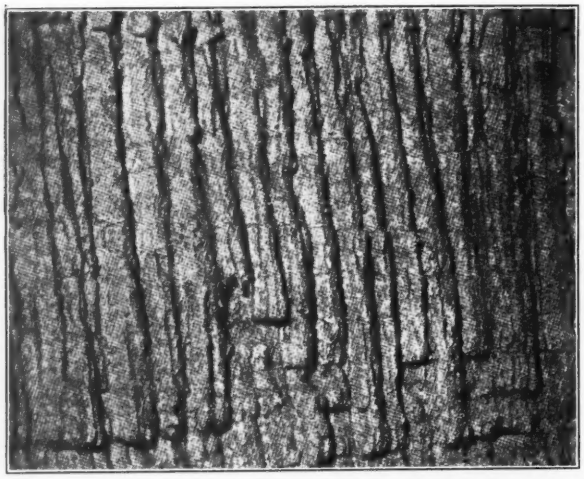


FIG. 3. ERODED BACK WALL OF FURNACE AT WINDSOR STATION, W. PENN. POWER CO.

a dense brick, probably because it is more flexible and absorbs the temperature stresses more readily.

Numerous laboratory tests have been suggested to determine the tendency of a brick to spall. These consist of heating the end of a brick to a certain temperature and then suddenly cooling it in water or by means of a jet of air. Such tests are of questionable value as the character of the brick soon changes in services in a furnace. Molten ash and gases of various kinds penetrate the face of the brick exposed to the fire and fill the pores. They generally react chemically with the brick and change its characteristics. A brick which spalls readily in a laboratory test may be altered under such action so that it stands up in a furnace. Usually, the penetration of slag and the vitrification of the end of the brick increase the tendency to spall.

Solution of the spalling problem consists in finding a brick which will stand up under the slagging action of the fuel used in the furnace without excessive spalling and in avoiding too sudden changes in furnace temperature. The common practice of leaving the damper open and drawing cool air through the furnace when a boiler is being shut down should be avoided, as this produces a rapid cooling at the face of the brick.

Erosion is the most serious refractory trouble encountered in burning bituminous coals. The ash of mid-western (U. S. A.) bituminous coals will soften at temperature of from 1900 to 2400 deg. F. As the temperature is increased above the softening point, the fused ash becomes less viscous and will finally flow as freely as water. The interval between the softening and running temperatures of coal ash may be 200 or 300 deg. but is much less with some kinds of coal.

All of the ash from pulverized coal is in suspension in the furnace and some of it will strike the walls. The flame from forced draft stokers carries considerable molten ash which is picked up from the fuel bed by the high air velocity and is deposited on the furnace walls. If the temperature of the fire brick is above the flowing temperature of the molten ash, the brick will be quickly eroded or washed away. The molten ash penetrates the brick, combines chemically with the impurities or binder and literally carries away the larger particles of brick by mechanical floatation. Figure 3 from the Prime Movers Committee report of the N. E. L. A. for 1926, shows the appearance of a wall which has been eroded by molten slag.

If the surface of the brick is at a temperature only slightly in excess of the softening temperature of the ash, the slag which adheres to the wall will be so viscous that it cannot penetrate the brick and will do no harm. The coating of slag may build up to a thickness such that the slag next to the hot furnace gases is fluid and runs while the slag next to the face of the brick is maintained at a sufficiently low temperature, by heat conduction through the brick wall, so that its velocity with respect to the brick is zero. The slag will then protect the brick. If the furnace temperature is now increased, the slag on the walls will run and, if the running temperature of the slag penetrates to the brick, erosion will occur. With some kinds of coal, a change of only a few per cent in boiler rating will melt off a protective coating of slag and cause serious erosion.

Fuel bed temperatures of 2700 and 2800 deg. F. are encountered with modern stokers. Flame temperatures of 2800 and 2900 deg. F. are found in pulverized coal and oil-fired furnaces. The temperatures at the surface of the refractory furnace lining may be within 100 deg. F. of these figures. The table shows the temperatures of the refractory lining in a furnace at the Fisk Street Station of the Commonwealth Edison Co. It will be noticed that the surface temperature of the brick at several points is in excess of the temperature of the gases next to the brick. This is due to radiation from a hot flame or hot section of the fuel bed which may be several feet from the brick. The maximum temperatures shown in the table are several hundred degrees in excess of the running temperature of the slags formed from many mid-western coals. Figure 4 for that furnace shows that a difference of 400 deg. F. in the maximum temperature of side wall brick made all the difference between no erosion and severe erosion.

Softening and running temperatures of coal ash slags depend to quite an extent upon the nature of the atmosphere. An oxidizing atmosphere causes the formation of ferric oxides; a strongly reducing atmosphere results in the formation of ferrous oxides. The melting points of the slags formed by a combination of the basic iron with the silica in the ash vary as much as 300 or 400 deg. F. and are always lower when the iron is in the ferrous state; consequently, severe localized side

wall and arch erosion is often due to the presence of a strongly reducing atmosphere and can be overcome by the introduction of sufficient air to produce an oxidizing atmosphere.

It is a difficult problem to secure a firebrick which is resistant to slag erosion. In many cases, the trouble is aggravated by the fluxing of the cement used in the joints, thereby exposing the sides as well as the end of the brick to slag penetration. The chemical composition of the ash is important, as erosion is often due to the formation of slags of low melting point by the chemical reactions which take place between certain constituents of molten ash and firebrick. In general, a dense brick will resist slag penetration and erosion better than a porous brick but is more liable to fail by spalling, as it is too rigid to absorb temperature stresses.

COMPARISON OF MAXIMUM TEMPERATURE OF REFRACTORY WITH TEMPERATURE OF FURNACE GASES NEAR REFRACTORY PIECE—FISK STREET STATION, COMMONWEALTH EDISON CO.

Position No.	Location	Maximum surface temp., deg. fahr.	Gas Temperature—Average	Gas Temperature—Maximum	Gas Temperature—Minimum
1	Nose tile. Center of ignition arch	2100	2000	2250	1650
2	Arch block. Center in middle of arch	2500	2270	2370	2100
3	Arch block. Center—2 ft. from nose of main arch	2600	2450	2630	2300
4	Arch block. Side of arch 2 ft. from nose of main arch	2600–2800	2530	2750	2350
5	Nose block. Center of nose of main arch	2600	2550	2690	2325
6	Nose block. Side of nose of main arch	2500	2690	2830	2615
7	Bridge wall. Block center of bridge wall	2500–2600	2182	2570	1850
9	9-in. brick. Front of side wall. Slight erosion	2300	2080	2750	1675
10	9-in. brick in side wall. Great erosion	2700	2370	2900	2080

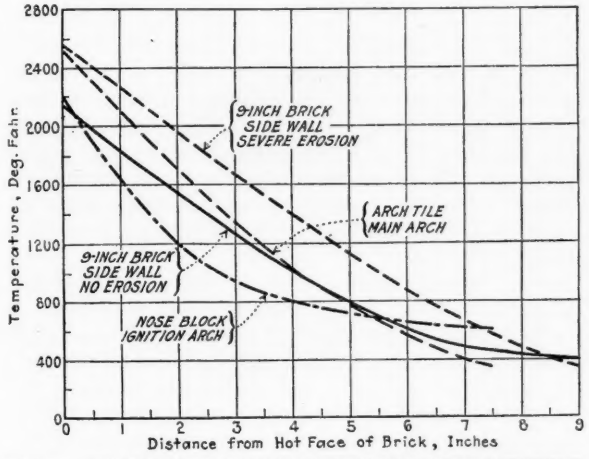


FIG. 4. TEMPERATURE FALL THROUGH REFRACTORIES IN CHAIN GRATE STOKER FURNACE

In a brick furnace, as the setting height of the boiler is increased, the ratio of water-cooled surface to brick surface decreases and the heat absorbing water-cooled surface is farther from the fuel bed or flame. Due to the decreased heat absorption by radiation, such an increase in setting height will increase the furnace temperature. At high rates of combustion and especially with good mixing or turbulence in the furnace, the rate of heat liberation is so great that the absorption of heat by radiation is insufficient to prevent the furnace temperatures from exceeding the fusing temperature of the ash from many coals. Excessive brick work maintenance thus becomes a factor in limiting boiler capacity and special furnace construction is necessary in order to overcome this difficulty.

Air-Cooled Furnace Walls

If the furnace side of a brick wall can be maintained at a temperature below the running temperature of the ash, a protective coating of slag will adhere to the brick and erosion can be prevented. To accomplish this, furnace walls may be built of hollow construction, most of the air required for combustion being drawn through the wall spaces to cool them and also to reduce radiation losses. Figure 5, from a paper by E. G. Bailey on Factors in Furnace Design before the A. S. M. E. Dec. 1927, shows pulverized-fuel furnace in which all four walls as well as the ash hopper are air cooled. Due to the wall thickness required for strength and the low thermal conductivity of firebrick, such cooling is ineffective when operating conditions are severe. If the furnace temperature is much above the fusing temperature

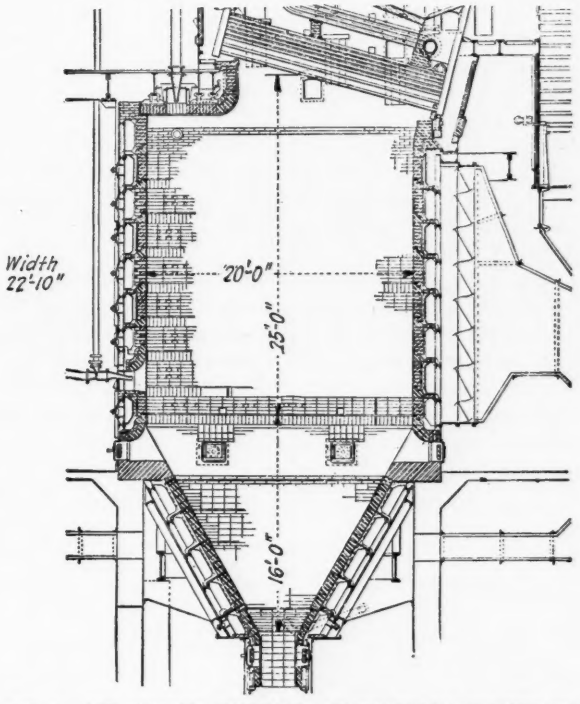


FIG. 5. AIR-COOLED FURNACE AT COLUMBIA POWER CO.

of the ash, the heat radiated to the face of the brick from the flame or fuel bed, cannot be conducted through the brick to the cooling air at such a rate as to keep the temperature of the brick below the ash fusing temperature. Where flame impingement on the walls can be avoided, the fusing temperature of the ash is relatively high and the furnace is so large that the energy release in British thermal units per cubic feet per hour is moderate, air cooled furnaces are successful in overcoming the limitations of a solid refractory wall.

Water and Steam-Cooled Furnace Walls

With ash of low fusing temperature and in high capacity furnaces, air cooling is insufficient to prevent erosion of the walls and more effective methods must

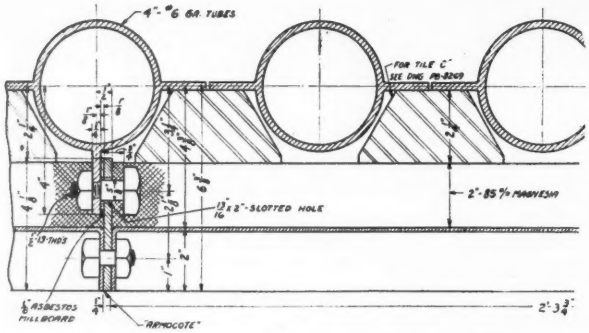


FIG. 6. SECTION OF C-E FIN-TUBE WALL

be used. Water and steam-cooled surfaces located in the furnace walls have the advantage of reducing the amount of brick work and also lowering the furnace temperature on account of absorption of radiant heat.

Installing vertical boiler tubes in the side walls is the simplest type of water wall construction, connecting them into the circulation of the boiler and building a solid refractory wall behind them. The tubes then serve to shadow the brick wall and protect it from excessive temperatures. Figure 6 shows the construction of the fin-tube furnace wall. Steel fins are welded to vertical 4-in. tubes, spaced on about 7½ in. centers, in such a manner as to present a continuous, metal, water-cooled wall to the furnace gases. The tubes are backed up by insulation which is attached to them as shown in the illustration, thereby eliminating the refractory wall.

In another common type of water wall, either bare or refractory-faced cast-iron blocks are clamped to tubes connected into the boiler circulation, thereby presenting a continuous smooth surface on the furnace side. Figure 7 shows the construction of a steam-cooled furnace wall in which two headers are connected by nipples to seamless forged steel elements which present a flat surface to the furnace.

Figures 8, 9 and 10 show the application of water-cooled walls to modern furnaces. Figure 8 is a water-cooled pulverized fuel furnace in which the rear and part of each side wall are of fin-tube construction and a water screen extends across the bottom of the furnace. Part of the side walls and the front wall are air-cooled. Figure 9 shows a pulverized fuel furnace, using turbulent burners, which is almost completely water cooled and is built of bare and refractory-faced cast iron blocks clamped to tubes. Figure 10 shows a similar type of wall construction applied to a chain grate stoker, where even the arches are water-cooled.

Water and steam-cooled furnaces have several advantages over brick furnaces. Maintenance is reduced because of the reduction or even complete elimination of the brick work, while lower furnace temperatures are brought about by the increased absorption of radiant heat. The common practice in brick furnaces of keeping down the temperatures at heavy loads by means of excess air can be eliminated, resulting in better efficiency. The capacity of water-cooled furnaces is much greater than that of brick furnaces and full advantage can be taken of turbulent burners for oil and pulverized coal. The problem of ash removal is greatly simplified. Heating surfaces in the furnace walls are effective as heat absorbers and add to the capacity of a boiler.

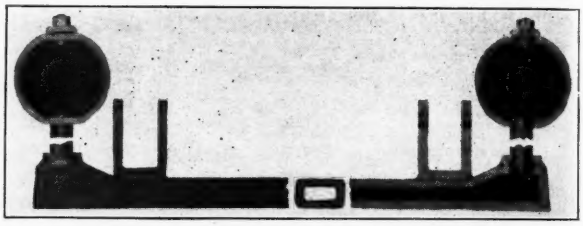


FIG. 7. RADIANT SUPERHEATER ELEMENT

On the other hand, water and steam-cooled furnace walls are expensive and require pure feedwater for their successful operation. This limits their application to central stations and to large industrial plants oper-

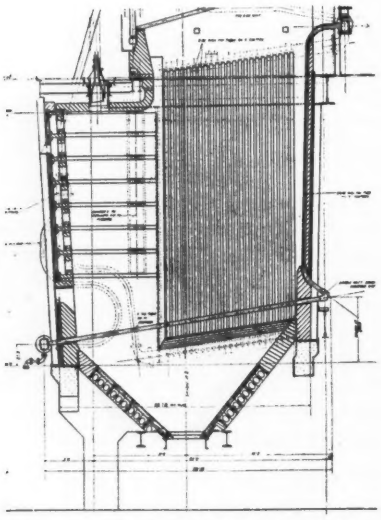


FIG. 8. WATER-COOLED FURNACE WITH AIR-COOLED REFRACTORIES

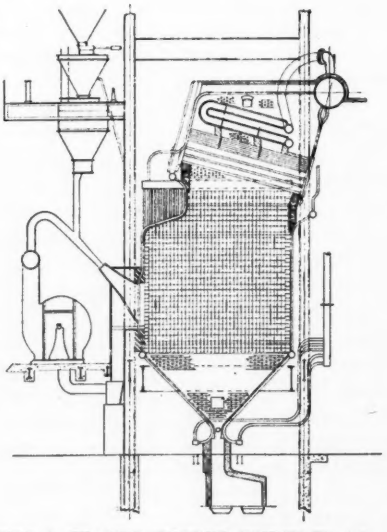


FIG. 9. WATER-COOLED FURNACE AT CALUMET

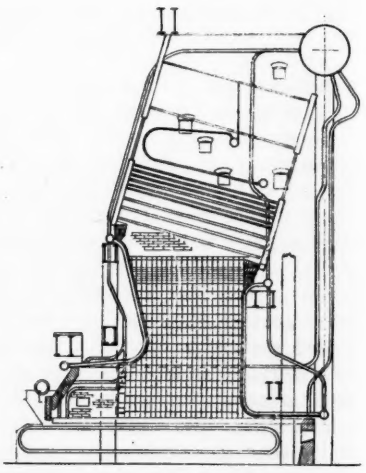


FIG. 10. WATER-COOLED SIDE WALLS AND ARCHES FOR CHAIN GRATE AT CRAWFORD AVE.

ating at high load factors, where maximum capacity is desirable and where the ash has a low fusing temperature. In small plants, the service is less severe, the load factor is generally poor, the feedwater is impure and it is generally cheaper to install air-cooled furnace walls or keep down the furnace temperatures during peaks by means of excess air than to install water-cooled furnaces.

Water-cooled furnaces must be designed with care to avoid excessive cooling. Over cooling will reduce the ignition rate and decrease the load which can be carried successfully as well as increase the cost of the

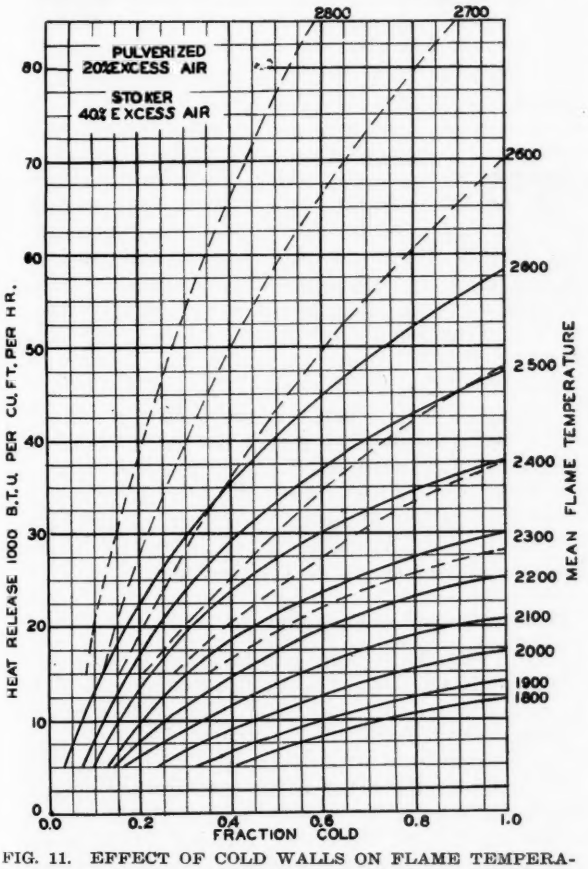


FIG. 11. EFFECT OF COLD WALLS ON FLAME TEMPERATURE. 8000-CU. FT. FURNACE. AIR AT 70 DEG. F. ILLINOIS COAL

installation. Under cooling will result in excessive temperatures at peak loads, slagging and brick work erosion. Figure 11 from Trans A. S. M. E., Vol. 50, Boiler Furnaces by Wohlenberg and F. W. Brooks shows the relation between furnace flame temperature, rate of energy release in British thermal units per cubic feet per hour and fraction cold, or fraction of total furnace surface which is water or steam-cooled, when burning Illinois coal on stokers or in pulverized form. The position and extent of water-cooled surfaces, type of fuel, method of burning, per cent of excess air, temperature of air supplied for combustion, size and shape of furnace and fusing temperature of the ash are the controlling factors. In general, pulverized coal can be burned in a completely water-cooled furnace, especially when the air required for combustion is highly preheated. High moisture or high ash coals may give better results if the front wall is of brick. With stokers, cooling can be overdone. Water-cooled side walls can be used with nearly all bituminous coals. With underfeed stokers, water-cooled bridge walls are advisable when burning the better grades of coal and complete cooling of all surfaces is being tried. With forced-draft chain grates, the use of water-cooled arches has sometimes resulted in too cold a furnace although water-cooled side walls are necessary in high duty furnaces.

A.S.H.&V.E. to Meet at Bigwin Inn, Ontario, June 26-28

FOR ITS SEMI-ANNUAL meeting June 26-28, the American Society of Heating and Ventilating Engineers will travel to Bigwin Inn, Ontario, Canada. This is a summer resort in the Lake-of-Bays district and is reached by way of Toronto. A special train will be run by way of Toronto on June 25; for those who wish to motor to Bigwin, detailed road directions will be supplied by the local committee.

M. Barry Watson is chairman of the committee on arrangements and further details regarding transportation, hotel reservations, entertainment features and so on, can be obtained through him. He can be addressed at Bloor and Balmuto Streets or 121 Welland Ave., Toronto, 5, Ontario, Canada. Grand-Trunk Canadian National Railways, 4 So. Michigan Ave., Chicago, Ill., can supply information about trains to Bigwin. Information may also be obtained from the secretary of the society, A. V. Hutchinson, 29 West 39th St., New York City.

Program for the meeting is as follows:

WEDNESDAY, JUNE 26

8:30 a. m. Registration.
9:30 a. m. Greeting by Ontario Chapter President.
Response by President Thornton Lewis.
The Measurement of Air Velocity, by Prof. J. H. Parkin.
Overall Heating Efficiency of the Research Residence Warm Air System Analyzed, by Prof. A. P. Kratz and J. F. Quereau.
Air Conditioning system of a Detroit Office Building, by H. L. Walton and L. L. Smith.
Report of Committee on Code for Testing and Rating, Unit Heaters by D. E. French, Chairman.

THURSDAY, JUNE 27

9:30 a. m. Report of Committee on Interpretation of Code for Rating Low-Pressure Heating Boilers, by L. A. Harding, Chairman.
Determining Dust Quantities in Air, by Prof. F. B. Rowley.
Capacity of Radiator Supply Branches for One and Two-pipe Systems, by F. C. Houghton, M. E. O'Connell and Carl Gutberlet.
Pipe Sizes for Hot-Water Heating Systems, by Prof. F. E. Giesecke and E. G. Smith.
Report of Guide Publication Committee, by S. R. Lewis, Chairman.

FRIDAY, JUNE 28

Report of Committee on Code for Heating and Ventilating Garages, by E. K. Campbell, Chairman.
Time Lag as a Factor in Heating Engineering Practice, by James Govan.
Overall Heat Transmission Coefficients as Determined by Test and by Calculation, by F. B. Rowley, A. B. Algren and J. L. Blackshaw.
Five Suggested Methods of Appraising Insulations, by Paul D. Close.
Report of Advisory Committee on Heating and Ventilating Exposition, by H. P. Gant, Chairman.

Does Slag Tapping Solve the Ash Problem?

INTRODUCTION OF MOLTEN SLAG METHOD OF REMOVING PULVERIZED FUEL ASH FROM THE FURNACE IS A NOTABLE DEVELOPMENT WHICH IS BEING WIDELY ADOPTED

SUCCESSES which have been attained by the present installations of slag tap boiler furnaces where the ash is removed as molten slag, have led to the introduction of such furnaces in many central stations where heavy firing with high furnace heat releases are desired.

These furnaces were first successfully used at the Charles R. Huntley Station of the Buffalo General Electric Co. where comparatively low fusion ash coals are burned. A number of other companies have since used the furnaces and the Mississippi Warrier Service has successfully adopted the system to pulverized coal-fired towboat service. Reports of two successful installations made to the N.E.L.A. are given below.

ANALYSIS OF THE COAL AND SLAG AT HUNTLEY STATION

Coal (Dry Basis)	Per Cent
Fixed carbon	53.29
Volatile matter	34.66
Ash	12.05
Sulphur	2.85

Fusing point of ash, about 1950 deg. fahr.

Slag Analysis

Silica (SiO_2)	44.52
Aluminum oxide (Al_2O_3)	18.64
Iron oxide (Fe_2O_3)	31.35
Titanium oxide (TiO_2)	0.76
Phosphorus pentoxide (P_2O_5)	0.25
Calcium oxide (CaO)	1.33
Magnesium oxide (MgO)	1.10
Sulphur trioxide (SO_3)	1.80
Undetermined	0.25

At Huntley, all four of the new boilers erected during the recent extension of the station were of the Babcock & Wilcox cross-drum type, 44 tubes wide and 11 tubes high, containing 12,500 sq. ft. of boiler heating surface. Each boiler is provided with a separate economizer. The furnace under the first boiler included a well 8 ft. square and 11 ft. deep, sunk into a furnace floor that was 17 by 25 ft. and averaged 12 ft. 9 in. to the bottom row of boiler tubes. The sides of this well were formed by 3¼-in. tubes on 6-in. centers covered on the fire side with solid Calorized-steel Bailey blocks. At the top of the well, these tubes were bent outward at an angle and ran uncovered through the furnace to the headers on the outside of each wall. The well floor was constructed of Carborundum tile covered by blocks of the same material. The bottoms of these tile formed the roof of a plenum through which the secondary air entered the furnace, flowing in back of the well tubes. No water tubes were installed in this floor. Burners were set in each wall halfway between the furnace center line and right-hand adjacent wall, in such a manner as to create a rotating effect when in operation.

It was expected that the cyclonic effect in the well would keep it free from ash, which would drop out as the gas expanded into the main furnace above the well; however, it soon became apparent that bare blocks would not withstand the high combustion rate of 1,100,000 B.t.u. liberation per cu. ft. of well volume, equivalent to 62,000 B.t.u. per cu. ft. of combined furnace and well volume.

Subsequent changes in the well blocking, in which the Calorized-steel blocks were replaced with refractory-faced Bailey blocks and the sloping wall tubes above the well covered with clay tile, served to increase the furnace temperature to the point where the ash became molten and dropped directly or ran from the clay tile into the well. This increased temperature reduced the carbon carry-over and improved combustion generally. That portion of the slag which ran down the clay tile banks on the sloping tubes continued downward into the well, flowing on the face of the wall. Upon reaching the floor, the slag formed a pool, remaining in the molten state because of the high temperature of the furnace above and the absence of cooling tubes below. This fluid could be tapped through a hole in the bottom of the well but the problem was to find a satisfactory means of disposal after tapping.

Analyses of coal and slag are given in the table. When solid, the slag had a very low coefficient of heat transmission, which made it a good heat insulation for the well floor, as the lower part of the slag solidified due to the passing of secondary air beneath the bottom of the well. This characteristic also added to the problem of handling, as will be discussed later.

Molten Slag Was First Allowed to Cool on Floor

At a high temperature and below its melting point, the slag was tough and viscous, like molten glass. When cool, it was a dense black solid, often with a coppery opalescence at a fracture; it was hard enough to cut glass and weighed approximately 200 lb. per cu. ft. When running from the slag spouts into the open air, the outer part of the stream congealed and the flow continued through the center, forming a tube or pipe. The original method of slag disposal, pending a solution of the ash-handling problem, was to allow it to run onto the floor each night before shutting the boiler down and remove it the next day with a pick and shovel gang. This method was mussy and, of course, impractical, involving a high labor cost and the concrete floor on which the hot slag was dropped chipped away, due to the heat. The slag would spread around the floor, working outward from a point underneath the spout, resembling a bed of molten volcanic lava. A water hose turned upon it served only to chill a skin at the surface, the interior remaining in the molten state and flowing onward, bursting through the chilled skin at various places.

While the status of the problem was as set forth, three additional pulverized fuel-burning boilers, of a different furnace design, were placed in service. These had furnaces 15 ft. 7 in. square with walls going straight up at both ends and expanding on the side to a width of 25 ft. 8 in. at an elevation of 7 ft. 6 in.

above the furnace floor. The well floor line was 30 ft. from the lower boiler tubes. The furnace walls were of the refractory-faced Bailey block construction and had the same tube spacings as the boiler previously described; there was, however, greater cooling surface and greater furnace volume. The well floor was supported on steel girders and consisted of a steel plate, over which were placed two layers of firebrick, covered with 6 to 8 in. of burned dolomite. These furnaces operated at a heat release of 37,000 B.t.u. per cu. ft. of total furnace volume, which is equal to 236,000 B.t.u. per cu. ft. below the top of the burners.

Ash in these boilers assumed the same molten form as in the previous boiler, but the slag spouts, being closer to the floor, made the solution more difficult. Numerous suggestions were offered as to the best method of disposal, such as refractory-lined larry cars, handling the ash in the molten state, pouring the slag into water-filled dump cars direct from the furnace and various combinations of sluicing and elevating into the cars. The spouts on the boilers last installed, however, were too low to permit an ordinary car to be placed beneath them and although handling molten ash in such cars is everyday practice around blast furnaces, it was considered too hazardous for installation in the boiler plant.

Sluicing Finally Solved the Problem

While the new furnaces were in construction, experiments were made of dropping the slag directly from the furnace into a concrete buggy filled with water. Strangely, no explosion occurred and there was little sputtering. The slag stream formed its own insulating tube to the bottom of the buggy and built up as if there were no water on top of it. The sheet metal casing on the bottom of the buggy became red hot long before the surface of the water showed any signs of boiling. When the bucket was half full of slag, it was rolled to one side and some fifteen minutes later it was emptied and the interior of the slag was still red hot.

Sluicing was then tried out by placing an 8-ft. length of 12-in. channel iron, sloped at an angle of about 30 deg. under the spout of the original boiler and placing two ¾-in. water nozzles at the top, so as to sweep the channel clean. The lower end discharged into an ash car. These tests on sluicing led to observations that were of great value in arriving at the final solution. The slag stream was broken into small pieces by the mechanical force of the jets, and these pieces in turn tended to shatter into smaller pieces, owing to the rapid chilling effect of the water made possible by the exposing of greater surface areas per unit volume of slag. These facts indicated the necessity of using comparatively large volumes of water and were responsible for Hydro-jet handling.

Then a test equipment was installed under one boiler. This consisted of three primary jets with three parallel streams, forming, owing to the close spacing, a water table within a cast-iron disintegrating chamber. On this the molten slag fell directly, being broken into small pieces and partly chilled at this point. Falling from here into a U-shaped cast-iron trough, the slag was carried crosswise of the building with the aid of two carrier jets for a distance of approximately 10 ft. and still further chilled in the process, owing to the additional cold water. This flow hit a cast-iron smashing plate, where it was turned at right angles into another U-shaped cast-iron trough running lengthwise of the building and discharging at a distance of approximately 50 ft. in the adjoining yard. Two additional carrier nozzles, working in tandem, were placed at the head end of this run. The results from this test equipment exceeded expectations. The slag was deposited in a fine granular state at the discharge of the chute.

Steps were, therefore, taken to provide a permanent installation but, owing to the fact that the best point for permanent disposal was about 1000 ft. from the boilers, it was found necessary to pump the mixture of slag and water after discharge from the Hydro-jet system. The layout decided upon is shown in Fig. 1. To meet this requirement, a pit was designed into which

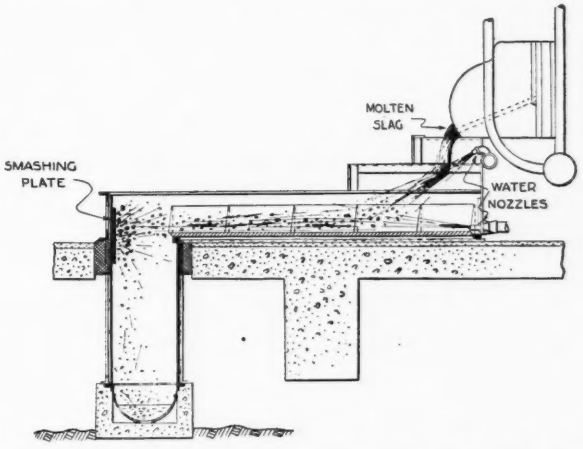


FIG. 1. LAYOUT OF THE HYDRO-JET ASH REMOVAL SYSTEM AT CHARLES R. HUNTLEY STATION

the sluices discharged. Two special manganese steel pumps, each of approximately 760 g.p.m. capacity, were provided for this service and a cast-iron suction pipe run into the discharge pit. All elbows in the suction and discharge piping are of manganese steel. One pump is intended for a spare, as both are connected in parallel to the same discharge main, which is of 6-in. steel pipe running along the side of the building and out across the adjacent land to the point of disposal. The pipe is pitched to make it self-draining and is not insulated. The material discharged spreads over a wide area instead of forming a pile beneath the pipe, as had been expected.

Slag Is Highly Abrasive

In operation, this system has worked out as satisfactorily as on test, although it has been found desirable to increase the pressure at the nozzles from 100 to 140 lb. in order to handle a higher rate of slag flow. These rates of flow are uncertain, being dependent upon the length of time the boiler is in service, the furnace temperature and the prior day's firing condition.

Tapping of slag from these four boilers requires the services of two men for a period of 1 to 3 hr. daily. The quantity of water pumped depends more upon the time required than upon the actual weight of slag removed, as it is necessary to provide enough water during the early stages of tapping to care for the maximum flow that may be encountered and this is a somewhat

indefinite quantity on account of the standby peak load operation of the station. The slag may vary from a mere trickle to a 6-in. diameter stream, coming fastest just after the flow is established and decreasing in amount as time progresses. When the flow decreases, the pressure at the jets may be throttled down as experience dictates.

As the slag is highly abrasive, renewable wearing plates were placed in the sluiceways at all right angle turns and were also placed in the concrete receiving pit to take the direct impingement of the slag bearing water.

It is remarkable that this installation, which is the first to be designed for handling molten slag from boiler furnaces by the Hydro-jet system, should have proved so successful from the start. Had not the low furnace floor levels of the boilers last installed made

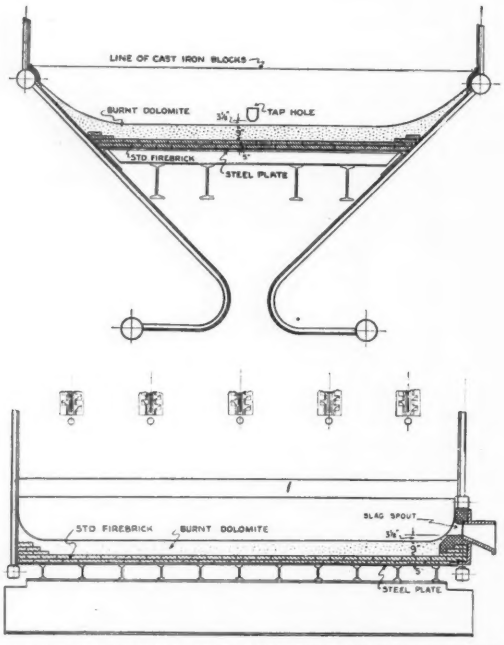


FIG. 2. TRANSVERSE AND LONGITUDINAL SECTIONS OF SLAG BOTTOM CONSTRUCTION OF BOILER NO. 5 AT TORONTO STATION

the handling of this slag in the molten stage by means of slag cars extremely difficult, this happy solution of the problem might not have been found.

Slag Bottom No. 5 Boiler at Toronto

At the Toronto Station of the Pennsylvania Ohio Power & Light Co., this method has also been successfully used.

Slag bottom of No. 5 boiler, a Springfield cross-drum boiler, having 21,620 sq. ft. heating surface, a water-cooled furnace surface of 2578 sq. ft., lined with refractory-faced block, and with Bailey walls on all four sides and on the ashpit slopes, is shown in Fig. 2.

The cooling surface, as originally designed, is divided as follows: side walls, 1247 sq. ft.; front wall, 726 sq. ft.; rear wall, 605 sq. ft., and hopper floors, 706 sq. ft., making a total effective cooling surface of 3284 sq. ft. The front and rear walls are covered with refractory-faced blocks. The side walls have all refractory-faced blocks, except the last four rows at the bottom, which are bare cast-iron blocks. The two ashpit slopes are covered with bare cast-iron blocks. The furnace has a volume of approximately 18,000 cu. ft. and is fired with five Calumet intertube burners, designed to burn 8000 lb. of coal per hr. each at maximum. These burners are equally spaced across the front wall, the coal entering the furnace at an angle of 45 deg. to the horizontal. The air for combustion is preheated to about 370 deg. F. by a plate-type-preheater.

Ash removal system originally installed on No. 5 boiler required a great deal of labor and close attention for successful operation. The ash accumulated on the side walls and slopes at low ratings and when the rating was raised on the boiler, this ash melted and avalanched down into the ashpit where, unless it was watched and dumped as fast as it came down, it blocked the ashpit gates or bridged over between the two ashpit slopes. When this happened, it was necessary to break the slag out with bars and long pipes in order to get the gates and the opening between the front and rear slope clear again. To overcome these difficulties, a new bottom permitting the liquid removal of the slag was designed.

Installation of this system required that the original bottom be changed somewhat. Four 21-in. I-beams are placed through the bottom parallel to the front and rear walls. On top of these and at right angles to them are placed eleven 9-in. I-beams equally spaced across the furnace from side wall to side wall. These 9-in. beams carry the ½-in. steel floor plate that completely covers the bottom. On top of this plate are two layers (5 in.) of standard fire brick and on top of the brick 9 in. of burned dolomite. A tap hole in the middle of the side wall is fitted with a cast-iron spout, which is closed by a gate operated with a wheel and worm gear. Suitable troughs, nozzles and breaker plates are provided to break up the slag and carry it to the ash sluiceway. About 35 tons of burned dolomite were put in the bottom and spread evenly over the fire brick and banked up against the sides and over the front and rear wall intermediate header. Figure 2 shows the construction of the bottom and the manner in which the dolomite was banked up.

Tapped Every 24 Hr.

This work was started March 14, 1928, and finished March 28, 1928. The furnace was not tapped the first day and the boiler was operated straight through without banking. Slag was tapped the first time after 27 hr. operation and again 4 hr. later. It was then found that the dolomite which had been banked up against the front and rear intermediate headers had been washed off of these headers onto the bottom. The boiler was banked the night of March 30 to solidify the dolomite on the bottom.

The tap hole is kept plugged with clay. In tapping, a bar is driven through this clay to the liquid slag. (An air-operated 'rivet buster' is now successfully used for this operation.) The slag runs out through this hole down the cast-iron spout and falls into a spray of water, which breaks it up and carries it about 4 ft., where it strikes a breaker plate and falls into another stream of water moving at right angles to the first. This stream carries it about 4 ft., where it strikes another breaker plate and drops into the ash sluiceway. From here, it is washed to the ash pump and pumped out to a fill. When the slag has been drained down to

the proper level, the tap hole is plugged with clay and the flow stopped.

Under normal operating conditions, the slag is tapped once every 24 hr. The average run takes about 1½ hr. This varies, however, depending upon the boiler rating and the ash in the coal. No trouble has been encountered at any time in keeping the slag hot enough to run. The temperature of the slag leaving the spout varies from 2300 to 2700 deg. F. The temperature naturally affects the speed at which the slag runs but at no time has it been low enough to retard the removal of the slag.

The coal burned is bituminous and comes from several mines in Pennsylvania and from a strip mine near the plant. The percentage of ash varies from 10 to 15 per cent and the fusion point from 1900 to 2200 deg. F. As an experiment, coal from eastern Pennsylvania containing 8 per cent ash and having a fusion point of 2900 deg. F. was burned in this furnace. This coal burned remarkably well, the slag liquefying and running as readily as that having a lower ash fusion temperature, but it was thought probable that this was because this coal was somewhat mixed with other coal having a low ash fusion temperature and another test was run on No. 4 boiler, which showed that Georges Creek Big Vein coal having an ash fusion temperature of about 2900 deg. F., could not be melted and tapped and in order to remove the ash, it was necessary to fire coal having a low ash fusion temperature so that the mixture of this ash with the ash already in the furnace formed a fluid which could be removed in molten form.

Only two leaks have developed in the bottom since its installation. One between the south side wall and the bottom about halfway back, dripped for a few minutes and then froze; the other, between the north side wall and the bottom at the slag spout, was a larger leak, requiring the use of a water hose to stop it. Neither leak did any damage nor affected the operation of the boiler.

The boiler has been in operation a little over six months with this type of bottom and no unforeseen problems of operation or maintenance have arisen. The ash pit now needs attention only while being tapped and when plugged can be forgotten until the next day. The slag comes to the pump in a fine granular state resembling ground black glass, the largest grains being about the size of buckwheat. The slag washes and pumps easily, and a large amount of slag can be handled in a fraction of the time required under the old system.

Slag Bottom No. 4 Boiler

Slag bottom No. 4 boiler is a Babcock & Wilcox cross-drum boiler with 20,470 sq. ft. heating surface and a water screen surface of 2100 sq. ft. The furnace as originally designed and constructed is of brick throughout. The side rear walls and bottom are protected by bare tube water screens. The center of these tubes is 6 in. from the walls and the tubes are spaced 10½ in. center to center. The side walls are of hollow wall-type construction, the secondary air passing through the walls from the rear to the wind box around the burners in the front. The furnace is 25 ft. high, 25 ft. long and 20 ft. 10 in. wide and has a total volume of 13,000 cu. ft. The boiler is fired with six Toronto-type Peabody burners in two rows of three each, one above the other, which fire horizontally through the front wall. The same coal is burned as in No. 5 boiler. The air for combustion is preheated to about 300 deg. F. in a plate-type-preheater.

In operating the boiler as originally constructed, the ashes accumulated in a hopper at the bottom of the furnace and from there were dropped into an ash sluice and washed to a pump from which they were pumped out to a fill near the plant. Difficulty was encountered with ash and slag accumulating on the sides of the hopper and on the water screen tubes. This was hard to get off and required a great deal of labor to keep the ash pits and water-screen tubes clean. Due to these difficulties and the labor involved, it was decided to experiment with a design of bottom to permit the liquid removal of the ash. The design of the bottom that was installed is shown in Fig. 3. This is a temporary installation and is sloped to follow the bottom water screen. The permanent installation will be flat.

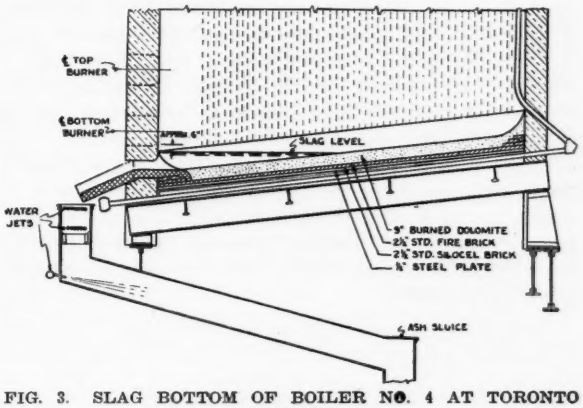


FIG. 3. SLAG BOTTOM OF BOILER NO. 4 AT TORONTO STATION

In changing No. 4 furnace, the rear wall below the water-screen tubes was cut out to permit the placing of I-beams to support the bottom. The bottom was built so that the tops of the 8-in. I-beams were above the tops of the water-screen tubes. On top of these beams were placed ½-in. steel plate, a layer of 2½-in. standard Silocel brick, a layer of 2½-in. standard fire brick and 9 in. of burned dolomite banked up around the edges. The tap hole was placed at the end in the corner, about 5 ft. from the center of the bottom right-hand corner. A refractory lined spout was placed so as to discharge the slag into a steel trough. In this trough are the water jets into which the molten slag falls and is broken up and carried along the trough for about 9 ft. Here it strikes a breaker plate, drops into another trough and jets and is carried to the ash sluice. The sluice carries the granulated slag to the ash pump from which the slag is pumped to the fill.

The boiler was fired up May 3 and was put on the line 8 hr. later. The boiler was tapped 8 hr. after this and the slag ran for 55 min. It was tapped again after another 8 hr. and ran for 35 min. The temperature taken with an optical pyrometer during these runs was 2760 deg. F.

After a day's run, the slag broke through the bottom about 6 ft. out from the front wall, directly in front of the lower-right-hand burner. The boiler was operated until it was convenient to take it off the line, when it was found that the Silocel brick had broken down under

the heat and exposed the steel plate to the slag. All the Silocel brick were removed and standard fire brick put in their place, making two layers of fire brick and 9 in. of dolomite on the furnace bottom. These repairs required about a day's time. A number of times, due to the temporary construction of the bottom, the slag leaked through the openings around the water screen tubes. None of the leaks were serious or caused any outage. The permanent installation will overcome this difficulty.

The boiler is tapped once each 24 hr., the average slag run being about 2 hr.; this varies, depending on how long the boiler has been on, the rating it has been operated at, and the ash in the coal. Up to this time, there has been no erosion of the brick work around the slag line.

Approximately 30 t. of dolomite were used in the bottom when it was put in and about 20 t. have been used since that time for repairs. There has been no change in the method of starting up the boiler. The same method is used with the slag bottom as was used before its installation.

Delray No. 3 Turbine to Take Steam at 1000 Deg.

REASONS FOR EXPERIMENT TO BE MADE AT NEW PLANT OF THE DETROIT EDISON CO. WITH 10,000-KW. BRITISH-MADE UNIT, STEAM FOR WHICH WILL BE SUPERHEATED TO 1000 DEG. BY A SEPARATELY-FIRED SUPERHEATER. BY J. W. PARKER*

DETROIT EDISON CO. has recently placed with the British Thomson-Houston Co., Ltd., Rugby, England, a contract for a 10,000-kw., two-cylinder, single-shaft steam turbine generator, to operate with an admission steam temperature of 1000 deg. F. The inlet pressure will be 365 lb. per sq. in. gage, conforming to the boiler pressure of the Delray Power House No. 3, in which the turbine is to be installed, while the exhaust pressure of 1 in. mercury absolute is that usually afforded in plants to which very excellent circulating water is available.

While The Detroit Edison Co. would have preferred postponing announcement of the plan of experimentation until more tangible accomplishment could be reported, it nevertheless seems advisable to make an authoritative statement now in order to correct misleading rumors which have become current.

*Chief Engineer, The Detroit Edison Co. This is the complete article that we received just as our June 1 issue was going to press, as noted on page 671 of that issue.

FIG. 1. OIL-FIRED TEST SUPERHEATER AT TRENTON CHANNEL. VERTICAL PIPE IS STEAM INLET; HORIZONTAL PIPE IS OUTLET CARRYING 1000-DEG. STEAM

REASONS FOR CHOICE OF HIGH STEAM TEMPERATURE

Choice of the unusually high initial steam temperature, 1000 deg. F., results from a study of the efforts of recent years to improve steam turbine efficiency. Improvement of the steam cycle has been affected by two limitations. One is inherent: the fact that moisture in the turbine exhaust apparently must not exceed about 10 per cent if rapid wear of blading and other parts in the lower pressure stages is to be avoided. Experience, in fact, has shown that entrained moisture may wisely be kept even below this amount. The other limitation has been the acceptance of 725 deg. to 750 deg. F. as the highest practicable initial temperature because of a cautious realization of the effects of temperatures higher than this on the strength of the metals ordinarily employed in superheaters, piping and turbines.

With such premises, increase of steam pressure as a means of raising the ideal efficiency of the steam turbine reaches an upper limit at about 450 lb. unless resort is had to reheating at some intermediate point of expansion. Obvious disadvantages of the reheating method, the added difficulty of plant operation and the markedly greater investment have made most central station managers and designers reluctant to adopt it, except for highly-developed, high-load-factor plants. This has often determined the choice, in recent plant design, of an initial turbine pressure of 400 or 450 lb. and the use of a straight regenerative cycle without reheating, involving acceptance of a turbine efficiency inferior to that of the higher pressure reheating plants.

The purpose of an experiment with higher temperature steam, therefore, is simply to remove (as far as permitted by our present knowledge of the behavior of alloy steels at such temperatures) one of the conditions preventing the use of pressures higher than 450 lb. in the simple regenerative cycle.

Choice of an English turbine manufacturer was determined by a number of considerations. One of these is the thought that the project is essentially experimental and, if the turbine were to be designed and built in this country, it could not fail of diverting interest, both in our own minds and those of the manufacturers'

engineers, from our established practice, which we believe should continue its tendency toward a standard design of turbine with major elements interchangeable within a large group of machines. Our long time acquaintance with the work of F. Samuelson and the turbine building experience of the British Thomson-Houston Co., Ltd., of which he is engineer and manager, led us finally to the choice of that company. Nor were we unmindful of the experience English metallurgists have had with the special steels that will be required to withstand the high temperature and of the proved skill of the British steel manufacturers.

It is planned to install the high-temperature turbine and its separately-fired superheaters in a corner of the boiler room in the new Delray Power House No. 3, where space has been left available by the omission of one boiler from the first battery in the plant. Steam taken

FIG. 2. LOOKING DOWN ON TEST SUPERHEATER. PIPES SHAPED LIKE WISHBONES ARE EXTENSIONS OF SUPERHEATER TUBES, SHAPED THUS TO PERMIT VERTICAL EXPANSION

from the main superheated steam line at 400 lb. pressure and 725 deg. F. will be passed through an oil-fired superheater designed to deliver a maximum of approximately 83,000 lb. of steam an hour, flowing thence directly to the turbine.

The machine itself will be placed close to the superheater in what would have been the longitudinal aisle between the first row of boilers and the auxiliary turbine room. So located, the run of pipe carrying 1000-deg. steam will be short and the condensing water connections will be simple. The energy generated will be delivered at 4800 v. to the local alternating current distribution system serving this district of the city.

Superheater for 1000 Deg. Is Installed at Trenton Channel for Experimental Work

As a preliminary step, an oil-fired superheater furnished by The Babcock and Wilcox Co. of New York has been set up in a vacant boiler position at the Trenton Channel plant. This superheater is now in operation taking 6000 lb. of steam an hour from the main superheated steam lines at 700 deg. F. and delivering it to a high temperature line at 1000 deg. The delivery temperature will later be raised to 1100 deg. After discharge from the superheater, the steam is desuperheated to approximately 700 deg. by admixture with saturated steam of the same pressure and is then delivered to one of the plant auxiliary turbines, operation of which affords a sufficiently continuous demand for steam to permit long experience runs. With this first installation, it is intended to obtain preliminary experience of the effect of high superheat on tubes, pipes and pipe fittings, particularly with respect to valves and pipe joints. Data obtained on the rate of heat transfer through tube surfaces under high superheat conditions will also be of value in designing the more permanent equipment for Delray.

Figure 1 was taken during construction of the trial superheater at Trenton Channel. The piping with bends in the vertical plane is carrying steam to the inlet fitting on which the safety valve is mounted, while the piping with the 90-deg. bend in the horizontal plane is the outlet steam line carrying 1000-deg. steam. Note the unusually heavy covering on this line. Figure 2 is a view looking down upon the superheater. What appear to be wishbone shaped pipe bends on top of the furnace are in fact extensions of the superheater tubes proper, divided into two groups of two tubes each and given this peculiar shape to permit vertical expansion of the furnace tubes.

Construction of Superheater

The entire surface receives its heat by radiation. It consists of rows of vertical tubes set in the rear and side walls of the furnace. They are completely shielded on the fire side by refractory tile and on the back are thickly insulated from the steel shell enclosing the whole structure. There are no tube headers as in the usual type of superheater; instead, four tubes leading from the steam inlet manifold carry the steam in four parallel paths through the superheater to the outlet fitting to which the tubes are welded. Each of these parallel paths consists of tubing, butt-welded together to form one length 275 ft. long and arranged with suitable return bends at top and bottom of the furnace wall, to form the grid of tubes already described as forming the back and sides of the furnace.

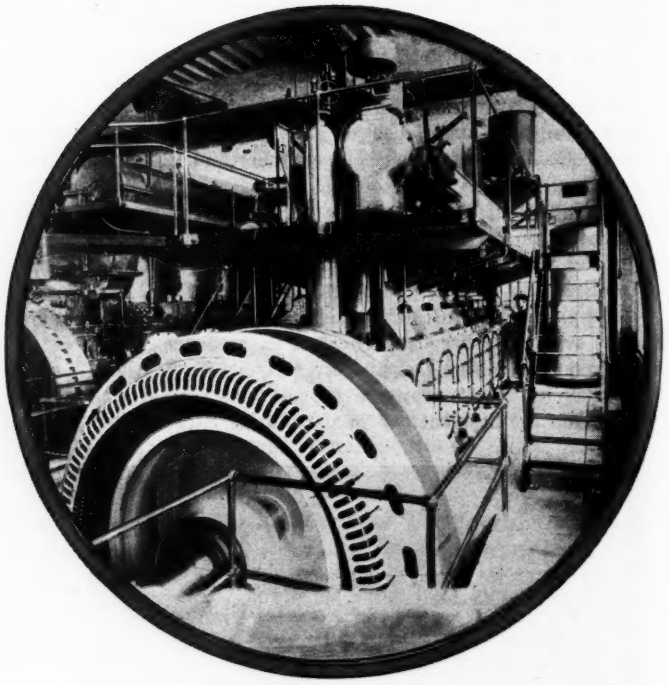
Whereas the material used in the tubes near the inlet and forming the back wall of the furnace is plain low carbon steel, the tube lengths in the side walls approaching the outlet are of special nickel chromium steel, as are the discharge piping and flanges. This nickel chromium steel can be welded satisfactorily and, as far as can now be determined, it is not brittle at high temperature, therefore it is safe for a fiber stress of 1000 lb. per sq. in. at 1100 deg. F.

Pipe line joints are at present Van Stone joints, with which gaskets of several different materials are being tried. Flanges are designed, however, so that Sargol joints can be made if that appears necessary.

As it is too early even to predict what results will be obtained in this initial experiment, the foregoing statement is intended as a definition of the problem and an announcement of present plants, rather than as a description of equipment and materials to be used in the final experiment.

Electrically-driven auxiliaries are now favored in most modern central stations because they allow the designer greater latitude in the heat balance.

Records Well Kept Show Excellent Performance

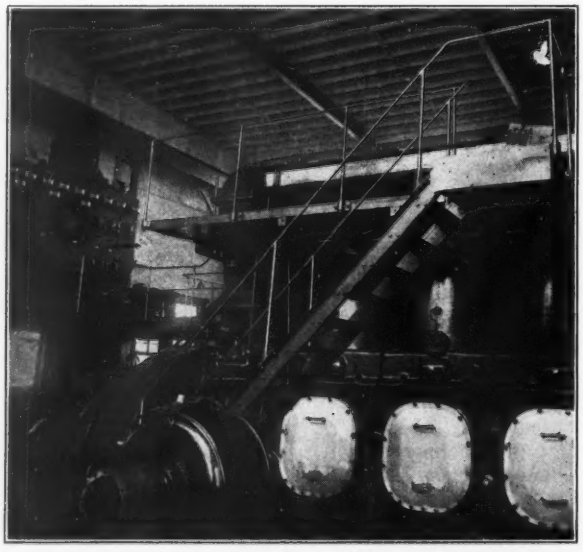


REDUCTION IN COST OF POWER BY HORTON MUNICIPAL PLANT HAS ENABLED THE CITY TO PAY FOR EQUIPMENT OUT OF EARNINGS AND REDUCE CHARGES BELOW ORIGINAL COSTS OF PURCHASED POWER. ELECTRICITY IS SOLD TO NEIGHBORING TOWNS AND ADJACENT SHOPS

SINCE THE CITIZENS of Horton, Kansas, took over the water and light plant by purchase from a private utility company in 1911, a total of $328,000 has been issued in bonds to defray the expense of the purchase and not only have the earnings of the plant retired $92,500 worth of the bonds but the department had $81,074.63 in cash on hand on December 31, 1928, in addition to $12,093.57 in the operating fund of the department. The present physical value of the plant is $467,426.56.

DIESEL EQUIPMENT REPLACES STEAM PLANT

Until the old inefficient steam plant had been replaced in 1921 by one of the Diesel type, no profit was realized in the light department even at the high rates then charged for electricity and until 1928 the water department showed no profit but increased sale of water during the past year resulted in the receipts being larger than the disbursements.



WORTHINGTON 562-HP. DIESEL ENGINE, SHOWING ALSO HOW SWITCHBOARD HAD TO BE INSTALLED ON A PLATFORM BECAUSE OF LIMITED SPACE

Dissatisfaction with the former service had been due not only to the high rate charged but also to the fact that electric current was available only from dusk until midnight and water was unfiltered and usually unfit for household use. Present equipment provides continuous service and sufficient units are installed to guarantee against loss of service.

FINE WATER SUPPLY

Horton's water supply now comes from a lake spread over an area of 210 acres and having a capacity of 700 million gallons. This water, which is unusually soft and of excellent quality is filtered and then sterilized by the ultra violet-ray method before it enters the distribution mains.

Motive power units now consist of three Diesel engines totaling 1562 hp. No. 1 is a 400-hp., four-cylinder McIntosh & Seymour Diesel oil engine direct connected to a 375-kv-a., 2400-v., 3-phase, 60-cycle Ridgway alternator operating at 200 r.p.m. This is furnished with a direct connected, 15-kw., 125-v., Ridgway exciter. This exciter is larger than would ordinarily be used because, at the time this unit was installed in 1921, the load had a low power factor.

Number 2 engine, shown at the left, which was installed in 1922, is a 562-hp., three-cylinder, Worthington Diesel engine, direct connected to a 500-kv-a., 2300-v., 3-phase, 60-cycle, General Electric alternator operating at 225 r.p.m. with a 15.5-kw., 125-v., General Electric exciter direct connected to it. The No. 3 engine shown in the headpiece of this article, which was installed in 1926, is a 600-hp., six-cylinder, 17 by 25-in., Worthington Diesel, direct connected to a 500-kv-a., 2300-v., 3-

TABLE I. OPERATING DATA FOR 1928

	Engine Hours Run				Kw-hr. Produced				Fuel Oil Used Gal.	Total Kw-hr. on board at plant	Kw-hr. per Gal. Fuel	Lub. Oil Used Gal.	Water Pumped Gal.	Alum Used Lb.	Kw-hr. Used Pumps & Ster.	Kw-hr. Used Disposal Plant	Kw-hr. Used by Rock Island	Water Used by R. I. Gal.	Kw-hr. Metered to Consumers	Rainfall Inches	Total Receipts		Running Expense		Maintenance		Extensions		Cost of Fuel Oil	Cost of Labor
	D. Eng.	E. Eng.	F. Eng.	A. Eng.	B. Eng.	C. Eng.	D. Eng.	E. Eng.													Light	Water	Light	Water	Light	Water		
Jan.	329	232	468	474	28560	37140	39240	115180	20095	174880	8.7	226	7878000	5050	10605	240	63318	5354375	136970	0.04	8548.69	3098.97	2621.91	516.18	*181.45 599.52	*981.19 274.47	1051.35	10.40	641.62	95.65
Feb.	215	201	424	474	28550	37140	105690	175560	17567	165560	9.4	170	6645000	4240	9306	4139	61949	4611750	132998	2.93	8257.99	1966.79	1632.23	535.39	*241.70 491.30	532.56	1020.84	2.60	662.58	194.27
Mar.	247	200	485	485	26010	37810	111860	175680	19115	175680	9.2	194	7820000	5225	10004	4679	75149	5170650	139403	.66	7355.98	1742.54	1453.06	347.20	325.35	342.45	1140.53	283.57	616.71	168.52
Apr.	276	191	457	485	26490	36180	111050	175920	15251	175920	9.5	190	8256000	5205	9171	4135	68614	4720500	130974	3.88	7625.74	2066.93	1393.44	475.90	772.89	615.86	1033.49	259.37	616.24	98.38
May	262	210	453	485	26910	41490	98100	176582	17586	166500	9.2	280	8570000	4215	10451	4377	70307	4572800	130801	2.56	6914.25	1620.67	4479.40	456.10	854.16	334.20	38.33	272.06	671.37	92.09
June	378	60½	463	463	43260	12350	106980	164570	0.9	164570	9.3	261	8205000	6900	9804	4347	69164	4358625	132454	9.24	6982.84	1854.44	1561.15	509.50	813.18	489.67	1552.85	536.48	560.74	284.00
July	440	49	466	466	52160	9530	109460	161491	17280	9.3	508	9763000	10800	12000	4274	70620	4683400	133954	7046435	4.96	8004.43	2475.38	1399.38	642.85	*181.45 1251.69	*981.19 699.28	1164.21	1941.85	546.86	173.03
Aug.	450	30	481	481	57160	6350	126280	189790	17735	10.7	192	8651000	6970	10173	4252	77535	6105000	146075	8177690	4.51	7174.98	1985.73	1467.50	1347.93	1504.98	385.63	427.40	971.05	647.09	92.66
Sept.	508½	6	405	405	52440	1110	116950	174911	17491	10.4	191	8109000	6660	12099	4147	70838	5413200	140077	7276935	3.39	7525.10	2196.45	1279.76	420.69	576.92	303.79	156.53	571.86	614.48	121.65
Oct.	505	18	467	467	53810	3970	137150	210288	20421	9.7	200	9329000	5400	11066	4497	84194	4969800	161549	6590750	3.23	7829.33	2034.62	1303.30	361.69	566.85	271.44	561.21	499.57	476.93	90.95
Nov.	548	32	446	446	57110	7700	136070	198254	21886	11.2	217	9820000	5760	11061	4190	76321	4507950	168051	6144500	5.81	8352.31	1732.77	1685.10	377.20	721.12	417.26	411.25	386.28	767.24	137.83
Dec.	571	31	469	469	72250	6910	132700	211910	21918	9.7	200	8629000	5700	11467	4748	75595	4588650	153956	6060200	.50	8548.02	1684.85	1674.64	361.78	408.11	177.05	182.07	107.40	523.59	121.64
Total	4824½	1250½	5552	5552	548090	239660	1411580	2280086	219270	9.74	2819	98173000	72805	127209	48034	865108	59292000	1701236	79559215	41.11	93115.60	23379.16	22189.47	6532.75	17918.40	11654.54	7740.07	5685.49	7440.41	1660.67

Existing - 50190 kw.
Power furnished towns: Willis - 29090 kw.
Netawaka - 44440 kw.

* Interest
† Bond $6000 Interest $951.19

Chief Engr. & Supt.

phase, 60-cycle, General Electric alternator operating at 200 r.p.m. with a direct connected, 16-kw., 125-v., compound wound, General Electric exciter.

Congestion Forces Unusual Switchboard Location

These engines are all crowded into a 46 by 37-ft. room, making it necessary to install the switchboard 7 ft. above the No. 2 exciter as shown in Fig. 1. During the past year, the No. 1 engine was given a thorough overhauling which included replacement of wrist pins, provision of one new piston and the rebabbiting and boring of the main bearings at a cost for new parts, amounting to $813.20. The No. 2 engine had been provided with a guided-skirt piston; this was replaced by a plain trunk-piston. The cost of the necessary parts was $2950 and the cost of extra labor required to make the change amounted to $125. Other than these major

TABLE II. CASH REPORT FOR 1928

Fund	*Cash on hand Jan. 1, 1928	Receipts	Transferred to	Transferred from	Disbursements	*Cash on hand Dec. 31, 1928
Water and Light	$11545.55	$116492.74		$44224.00	$ 71720.72	$ 12093.57
Street and Alley	1133.36	6713.91		1000.00	6035.44	811.83
General	632.51	10211.01	500.00		10035.31	436.21
General Sinking	12715.29	2406.58	1048.47	10321.51	2085.74	4289.06
Fire Maintenance	953.17	2850.16			2644.45	1158.88
Interest	7125.40	7118.84	847.25		8151.17	6934.32
Sewer	1166.54	1232.24			1155.12	2263.66
Sewer District Three	14355.09	26090.82		27223.39	13229.52	
Paving	8233.75	29689.40			32168.29	5757.86
Water and Light Sinking	20958.28	1488.07	73421.65		76793.37	19074.63
Bond Sinking (W. & L.)	15000.00	71135.69			64135.69	22000.00
Park	130.58	545.07			353.99	321.66
Rest Room	27.75	681.34			600.00	179.09
Highway Maintenance		708.33			352.40	355.93
Investment (General Sink)		10350.70				10350.70
Band		545.07			545.07	
Library		1362.68			1362.68	
Paving Project "F"		942.36	7000.00	645.47	7296.89	
Total	$94068.27	$290563.69	$83414.37	$83414.37	$259862.76	$125069.40

*Cash on hand and invested

changes, the average monthly cost for repairs and replacements has been $50.

Power Sold to Neighboring Towns

Power is furnished not only for the city of Horton but also for the Rock Island Railroad shops, which are near by and for three neighboring towns. Water pumped in 1928 amounted to 98,173,000 gal., of which 79,559,215 were furnished to consumers. Water is also furnished for street cleaning, sewer flushing and other municipal needs. Power produced for lighting amounted to 2,193,270 kw-hr., of which 1,701,236 kw-hr. was furnished to consumers in 1928, the sewage disposal plant consumed 48,034 kw-hr. and the pump and sterilizer, 127,209 kw-hr. Besides this, the city hall was lighted and current was furnished for street and alley lighting including a "white way." Station power is small, the three water-circulating pumps being operated by 5-hp. motors.

Operation of the plant is carried on by three 8-hr. shifts. Three men compose the day crew, which is on duty from 8:00 a. m. to 4:00 p. m., and they do all the ordinary repair work of the plant, one usually looking after the engines while the other two are on plant work. The other two shifts each have one operator.

Reduction in Rates Follows Efficient Operation

Efficient operation of the plant has gradually led to reduction in electric rates until 1928, when they reached the following scale, which is now in force:

Lighting:

First 50 kw-hr., 8 cents per kw-hr.
Next 150 kw-hr., 6 cents per kw-hr.
Next 800 kw-hr., 4 cents per kw-hr.
All over 1000 kw., by contract.

Power:

1 to 200 kw-hr., 5 cents per kw-hr.
201 to 400 kw-hr., 4 cents per kw-hr.
Over 400 kw-hr., 3 cents per kw-hr.

Cooking and Heating:

1 to 400 kw-hr., 4 cents per kw-hr.
All over 400 kw-hr., 3 cents per kw-hr.

TABLE III. MONTHLY REPORT OF WATER AND LIGHT DEPARTMENT FOR FEBRUARY, 1929

RECEIPTS

			1928	
LIGHT AND POWER				
Consumers	$4,841.91		$4,486.74	
Shops	2,007.89		2,626.72	
Whiting	314.00		256.00	
Metaweka	238.00		464.00	
Willis	141.00	$7,542.80	129.50	$7,962.96
WATER				
Consumers	986.90		1,048.24	
Shops	729.56	1,716.46	697.37	1,745.61
SUNDRIES				
Dep. Rec'd $ 68.00				
Dep. Ret'd 109.98	41.98*(in red)			
Material Sold	9.00			
Refund, Spur Track	36.00			
Labor, Ice Cutting	13.87			
	58.87			
	*41.98	16.89		72.81
			Co.Treas.	443.40
		$9,276.15		$10,224.78

DISBURSEMENTS

RUNNING EXPENSES				
Light:				
Superintendence	$ 250.00			
Engineers	430.00			
Fuel Oil	837.89			
Lubric. Oil	133.17			
Plant Supplies	59.61			
Line Labor	255.20			
Line Supplies	95.98			
Lamps	70.06			
Labor, General	90.00			
Supplies, General	35.23	$2,257.14		$2,113.26
Water:				
Engineers	80.00			
Labor	155.00			
Plant Labor	1.60			
Plant Supplies	11.48			
Reservoir Labor	12.80			
Reservoir Supplies	39.56			
Line Labor	147.60			
Line Supplies	56.62			
Convention Expense	9.25	513.91		1,067.69
EXTENSIONS & BETTERMENTS				
Light:				
Plant Supplies	296.05			
Line Supplies	201.02	497.07		20.84
Water				2.60
INTEREST PAID				
Int. W&L Refg.Bonus	594.66	594.66		861.70
			Engine Lease	1,000.00
		$3,862.78		$5,066.09

Engine	Hours Run	Hp-hr.	Kw-hr.	Peak Load - 750 kw.
1	397	158,800	51,670	
2	44	24,728	9,700	
3	431	258,600	123,960	
	872	442,128	185,530	

Fuel Oil Used	18,952 gal.	9.7 kw-hr. per gal.
Lubricating Oil Used	168 gal.	2,631 hp-hr. per gal.

Sewage Disposal Plant Power	4,186 kw.
City Hall, Light	398
City Hall Water	13,425 gal.
White-Way Lights	1,890 kw-hr.

Rock Island:

Water	4,107,900 gal.
Power	72,229 kw-hr.

Water Pumped	8,750,000 gal.
Pumps Used	8,010 kw-hr.
Sterilizers Used	979 kw-hr.
Alum Used	3,600 lb.
Lime Used	--
Rainfall	.52 in.

WATER & LIGHT DEPARTMENT

H. L. Lenger Supt.

Minimum charges are provided for each case. The station costs for 1928 averaged $0.0101 per kw-hr. for power and $0.077 per thousand gallons for water.

Disbursements made during 1928:

Plant operation (light)	$20,071.38
Line maintenance (light)	9,438.83
Extensions (light)	7,740.07
Plant operation (water)	7,438.80
Line maintenance (water)	4,098.45
Extensions (water)	5,603.51
Reservoir maintenance and extensions	1,241.70

From the cash report for 1928, shown in table, it will be seen that the 1928 earnings for the water and light plant were $44,772.02. Earnings properly applied have also aided in establishing a low city tax rate, the one levied last year being only 13 mills.

Much of the success in reducing operating costs is due to the excellent records kept in this plant, which indicate, from time to time, places in which improvement may be made and which constantly keep before the operators an urge to better their past records.

Turbine Types Meet All Conditions

FIVE CLASSIFICATIONS of turbines are in general industrial and central station service. They are: straight condensing; noncondensing or high back pressure; low pressure; mixed pressure and extraction.

In straight condensing turbines, steam is expanded from the throttle down to condensed pressure in the turbine. If the back pressure is atmosphere or higher, the machine is said to be noncondensing or high back pressure, depending upon whether the discharge pressure is atmosphere or higher, while if the turbine receives low pressure steam, for instance, from the discharge of noncondensing engines as was common a few years ago, it is a low pressure type.

Frequently, these low pressure machines were fitted with high pressure blading, so that high pressure steam could be used during periods when high pressure steam was not sufficient to carry the load. The turbine was then called mixed pressure type. Other turbines are so arranged that some of the steam can be taken off at one or more intermediate pressures between the throttle and condenser pressure, and this type is known as an extraction or bleeder turbine.

Combinations of the foregoing types are now common. Thus all large turbines are now made for extraction at several points and are often built in two or more sections and called tandem or cross compound units. Sometimes the steam is resuperheated between elements to give higher efficiency.

For industrial purposes, a combination mixed pressure and extraction machine has been developed. The machine will operate on high pressure or low pressure steam, or steam can be extracted. It can be used straight condensing, as an extraction unit, as a mixed turbine, or as a high back pressure machine. In the latter case, not all the steam can be extracted; approximately 10 per cent of the throttle flow must be passed through to the condenser to cool the low pressure blades.

DIESEL ENGINE development in this country during the past few years has been toward high-speed, solid injection engines. This is due largely to the fact that such engines, particularly those of the two-cycle types, are mechanically simple and rugged and thus meet the demands of the smaller industrial plant. Furthermore, it is of lighter construction and usually sells for a lower price than competitive air injection designs.

Power As a Factor in Recent Economic Changes

CHARACTERISTIC CHANGES DURING THIS PERIOD HAVE BEEN DUE TO THE USE OF POWER AND THE INCREASE IN EFFICIENCY OF EQUIPMENT*

ACCELERATION, rather than structural change, is the key to an understanding of our recent economic development. Gradually the fact emerged, during the course of this survey, that the distinctive character of the years 1922 to 1929 owes less to fundamental changes than to intensified activity. Changes have not been fundamentally new but the breadth, scale and tempo of recent developments give them new importance.

Broader understanding of economic forces, more general coöperation in avoiding pitfalls and a larger measure of self restraint on the part of all elements in the business, financial and industrial world, has resulted

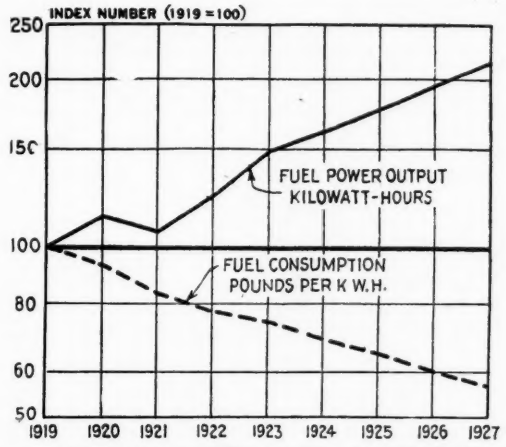


FIG. 1. RELATION BETWEEN FUEL CONSUMPTION PER KILOWATT-HOUR AND TOTAL OUTPUT OF ELECTRICAL ENERGY

in the period from 1922 to the spring of 1929 being of unusual stability as well as of intense activity, in spite of the fact that this activity has been spotty, with certain groups more active than other groups, certain industries busier than their neighboring industries and certain geographical areas more prosperous than other areas.

Characteristic of this period has been the rise in the use of power—three and three-quarters times faster than the growth of the population—and the extent to which power has been made readily available, not alone for driving tools of increasing size and capacity but for a convenient diversity of purposes in modern business enterprises, on the farm and in the home.

The increased supply of power and its wider uses; the multiplication by man of his strength and skill to machinery, the expert division and arrangement of work in mines and factories, on the farms and in the trades so that the production per man hour of effort has risen to new heights; the quickening of these instrumentalities through capital provided from the surplus sufficient incomes of a constantly widening proportion of our people—all these represent a stimulation of force which has long been at work.

Factories no longer need cluster about the sources of power. Widespread interconnection between power plants arising out of increasing appreciation of the value of flexibility of power made possible by technical advances during recent years has created huge reservoirs of power so that abnormal conditions in one locality need not stop the wheels of industry.

U. S. NOW USES AS MUCH POWER AS THE REST OF THE WORLD COMBINED

Increasing flexibility with which electricity can be delivered for power has enabled manufacturers and farmers to meet high labor costs by the application of power driven specialized machines. Power in this flexible form has penetrated into every section of the United States. This survey shows that as a nation we now use as much electrical energy as all the rest of the world combined.

Through the subdivision of power the unskilled worker has become a skilled operator, multiplying his effectiveness with specialized automatic machinery and processes. Thus the unit cost of production has been reduced, the drudgery eliminated from much unskilled work and wages maintained or actually increased.

Unfortunately not much can be said in regard to changes in efficiency as regards prime movers in use in manufacturing plants. Where new power plants are installed, they make use of the most efficient equipment available but many plants are old and are operated under disadvantageous conditions with generally low efficiency.

It is still good economy to use an engine as a reducing valve, especially when the engine is there already and is in good mechanical condition. As to the economy of steam power in the average industrial field, there is little or none when there comes a large demand for industrial or process steam.

For a certain large industrial establishment where considerable process steam and power are needed, the tendency is toward higher boiler pressure with steam turbines as reducing valves, even with steam mains with more than one pressure intermediate to the boilers as a maximum and the low process pressure, which is the back pressure of the turbine, as a minimum.

Where process steam is not the determining factor and the demand is merely for mechanical power, the choice usually lies between either purchasing power from a steam or hydroelectric central station or using oil engines. When conditions other than that of available power determine the location of a manufacturing plant, so that it is completely out of reach of the power line of the central station, the oil engine is in high favor.

These, of course, are normally in smaller plants. The oil engine also has a practical application in smaller central stations supplying light and power to towns and

*Taken from the report of the committee on Recent Economic Changes of the President's Conference on Unemployment, this survey, which was preceded by the Business Cycles and Unemployment Survey in 1922-1923 and the Seasonal Operation in the Construction Industry Survey made in 1923-1924, was begun in January 1928 and completed in February 1929. It is an analysis of post-war developments of American economic life, particularly those since the recovery from the depression of 1920 and 1921. The basic investigations of the committee were made under the auspices of the National Bureau of Economic Research with the assistance of an unprecedented number of governmental and private agencies.

villages located far from transmission lines of steam or hydroelectric stations. Diesel engines are also being installed as standbys in hydroelectric central stations and even in a number of manufacturing plants using purchased electric power, where certain processes are carried on and which would result in serious financial loss if there were any interruption of power supply.

A record of central station power is quite different. Facts available show that considerable progress has been made in decreasing the consumption of fuel per kilowatt-hour of fuel power generated. Figure 1 shows the changes that have taken place from 1919 to the present time, during which period remarkable improvement has

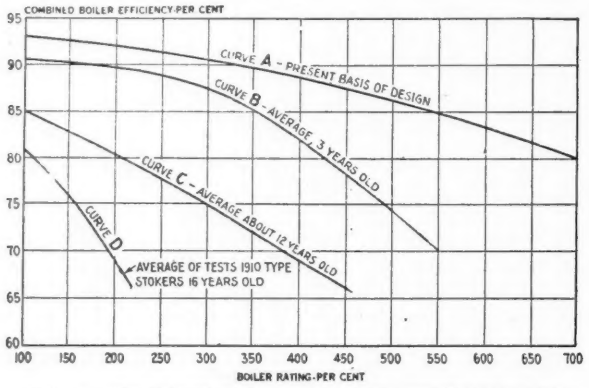


FIG. 2. IMPROVEMENT OF BOILER EFFICIENCY IN RECENT YEARS

occurred, the consumption of fuel per unit of electrical energy being only 55 per cent of what it was in 1919. During this period, the output of energy increased from 24,315 millions of kw-hr. in 1919 to 51,103 million kw-hr. in 1928. During this period, the fuel consumption decreased from 3.20 to 1.76 lb. of coal per kw-hr.

Advance in design of construction and operation of large steam central stations has been practically along three lines: First, larger generating units, using steam turbines as prime movers and larger boilers; second, higher steam pressure and superheat temperatures; and third, greater use of waste heat recovery apparatus. To these might be added improvements in all auxiliary machinery and of the overall efficiency of operation. A rough idea of the advance in efficiency may be had from the fact that one station generating 20,000 to 100,000 kw., the present rate of coal consumption is about 2 lb. per kw-hr. against about 3.5 lb. per kw-hr. ten years ago. Heat economies have also been introduced all the way from the furnaces of the last expansion stage to the turbine.

Today modern central stations have three ranges of pressure; first, around 400 lb. per sq. in.; second, from 550 to 750 lb. per sq. in. and third, from 1000 to 1400 lb. The greatest activity at present is in the first and third ranges, the intermediate one being proportionately neglected. In the choice between these two, the basis of selection is partly a matter of load, but more a matter of coal prices. For a cheap coal, with a small average load, the 400-lb. range is preferred. With a higher priced coal and a high average load, the 1000-lb. range is preferred. Both may be found at the same stations. Thus, in modern existing stations with units already in use operating at 400 lb. or less, 1000-lb. boilers can be added and high-pressure turbines can use this steam, exhausting it to the lower-pressure steam mains, and after reheating, using it in the lower-pressure turbines.

Temperatures are now limited to about 750 deg. F. because the metallurgists have not been able to produce a steel at a usable price that is perfectly reliable for higher temperatures. The tendency however is upward and 800 to 850 F. are already in use to a limited extent. There is a tendency also toward larger boilers and units in common operation today are good for over 400,000 lb. of steam per hour. Others now under erection have a specified capacity of 1,000,000 lb. of steam per boiler per hour. It seems probable that the practice will soon be to provide each turbine with its own boiler, no matter how large the turbine.

Diversified Electric Load Improves Operating Condition of Stations

Interconnection of stations has also extended, making it unnecessary to have both peak load and base load units in one and the same station. Interconnection also improves the average load because peak load on one part of the system does not occur at the same time as on the other. This is noticeable in one district where a large industrial load is just going off at the same time that the electric traction load in a nearby city is just rising to its peak during the evening.

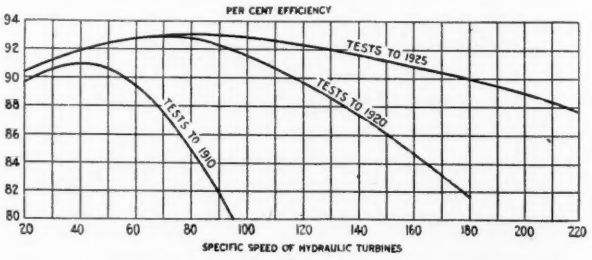


FIG. 3. INFLUENCE OF IMPROVEMENTS IN HYDRAULIC TURBINES ON THEIR EFFICIENCY AT VARIOUS SPECIFIC SPEEDS

Improvement in boiler efficiencies have been toward the attainable maximum, a fair statement of the change in well-operated plants being indicated in Fig. 2. This shows in curve A what may be expected for boiler and stoker performance on the basis of modern plants at 100 to 700 per cent rating. Curve B is on the basis of boilers three years old, curve C on an average of those about 12 yr. old and curve D was developed from a group of tests from stokers and boilers 16 yr. old.

In fuel, the outstanding change the past few years has been in the growth of pulverized coal installations. The extent of the use of fuel in this form is indicated by the fact that at the present time 40 public utilities in the United States are either partially or fully operated with pulverized coal. The aggregate generator capacity so far has been 2,200,000 kw. In addition, there are now under construction five new plants and extensions to two old plants, having together a total capacity of 440,000 kw., all of which will be operated with pulverized coal.

Recent improvements in the design and construction of hydraulic turbines has increased the efficiency, particularly in the higher specific speed. This is shown in Fig. 3, which is based on models tested at Holyoke for the three years 1910, 1920 and 1925.

New English Oil Engine Uses Airless Injection

NOVEL ARRANGEMENT OF OIL SPRAYS AND OF PORTS FOR IMPROVING SCAVENGING IS EMBODIED IN NEW RICHARDSON-WESTGARTH SEMI-DIESEL ENGINE. BY F. JOHNSTONE - TAYLOR

ALTHOUGH THERE MAY be a diversity of opinion still as to the relative merits of airless and air injection for oil engines, the latter is now mainly used on stationary engines of large output. Up to the present

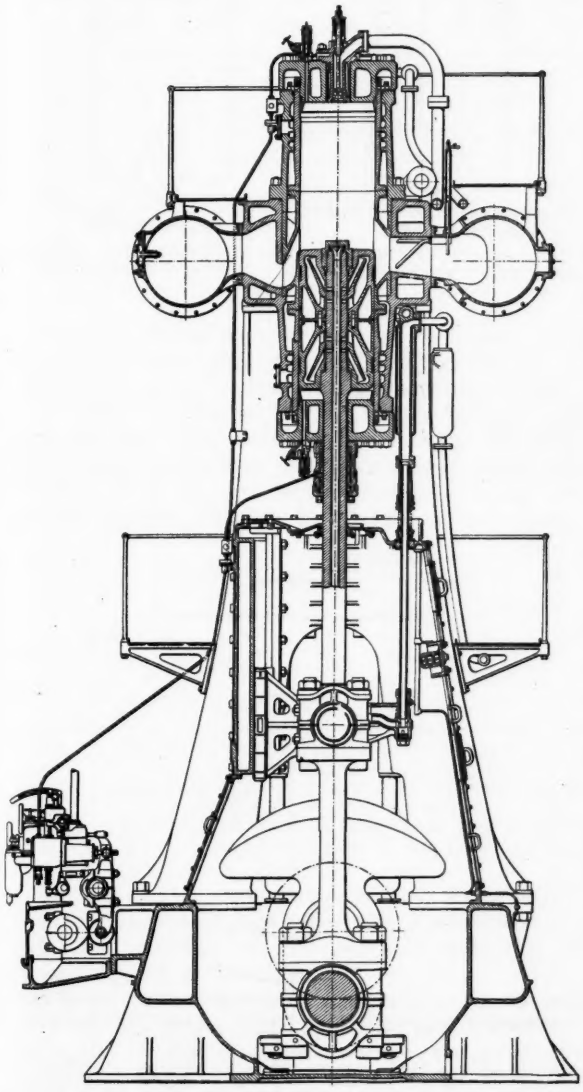


FIG. 1. NEW RICHARDSON-WESTGARTH DOUBLE-ACTING, TWO-CYCLE, SEMI-DIESEL ENGINE

time, no great effort has been made to cheapen the construction of large oil engines and it is well known that the large double acting engines which have proved so successful in marine work, are costly to build. In order to keep down weight and dimensions and at the same time simplify construction as much as possible, the majority of these engines are of the two-cycle type. A further step towards the same end lies in the adoption of airless injection.

An engine so constructed approaches as nearly as possible to the steam engine, in both simplicity and regularity of action. The reason for the retention of air injection in large engines lies mainly in the fact that it better facilitates efficient combustion of the lowest grades of Diesel oil and so tends to reduce fuel consumption to well below 0.4 lb. per br. hp-hr. in addition to maintaining regularity of running at low speeds but it must of necessity add to the cost of an otherwise costly power unit and this limits its field.

AIRLESS INJECTION APPLIED TO LARGE OIL ENGINE

The application of airless injection to the Richardson-Westgarth double-acting, two-cycle engine which is regarded as an important step in the progress of English oil engine design, is illustrated in section in Fig. 1. This is intended for an engine having an output of 1200 hp. at 90 r.p.m. with cylinders 21½ by 38 in. The bed-plate of the engine is of the box-girder type with a self-contained oil sump. The longitudinal members are only a little over half the depth of the transverse members; an arrangement which affords easy access to the external holding down bolts.

Four main columns, which are of the "A" type and in box form, constitute the frame. They are made in halves to facilitate casting and carry bosses at the front for the crosshead guides. From the top of the cylinder flange, the tie bolts, which are in tension and absorb all the working forces, pass inside of the columns through the main bearing to the underside of the transverse bed-plate girders. The crankshaft is of the built-up type with cast-steel webs and large counterweights; the latter acting with the self balanced scavenge pumps abolishes entirely the need of a flywheel. Located at the end of the engine, these scavenge pumps are quite unique in their arrangement of opposed pistons but practically perfect balance results and a light construction, largely due to the use of aluminum, is made possible. Chain driven rotary valves are employed. The pumps, which are gear-driven from the crankshaft at three times engine speed, may also be alternatively arranged for electric drive. They have a volume 50 per cent in excess of the piston displacement of the working cylinders.

SECTIONAL CYLINDER LINER PROVIDES FOR EXPANSION

Examination of the cylinder and piston design reveals at once the simple method employed for applying good engineering principles. The cylinder liner is made in three sections resting on the top of the cylinder jacket and secured by through-bolts. It is water-cooled, cored for the necessary air and exhaust passages and recessed to take the central portion of the liner. The assembly of the central belt and the two liners is shown in Fig. 2. From the section, it will be noted that the lower cylinder jackets are cast integral with the frame, though the upper jackets, while similar in form, are separate castings. The center portion of the jacket embodies the

necessary air and exhaust ports and water circulation in the port bars which makes it an intricate and difficult casting to make from the foundry point of view.

Acceptance of the final design was made only after considerable experimentation to determine the best shaped nozzle ports required to give the maximum degree of scavenging. The manner in which this was effected is shown in Fig. 3; the behavior of the air in the other half of the cylinder being similar to that shown. The first stream of air proceeds directly to the cylinder head and no automatic scavenge valves are required. Both the upper and lower liners, as shown in Fig. 2, are similar, interchangeable castings, bolted to the central portion, their outer ends fitting into packed glands in the water jackets. The cylinder heads

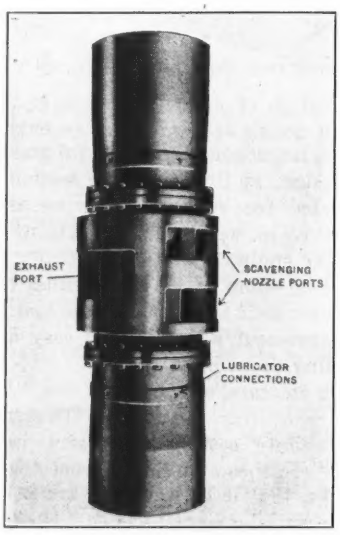


FIG. 2. CYLINDER LINER MADE IN THREE PARTS BOLTED TOGETHER, THE TWO OUTER PORTIONS BEING ALIKE IN CONSTRUCTION

project into the liners, the necessary gas tight joint being formed by a patented spring gland.

Where the edge of the head comes in contact with the liner surface, it is fitted with a packing ring of special heat-resisting steel, the object of which is to protect the liner surface and to assist in promoting good combustion. The cooling water system is so arranged that the fuel valve bodies are entirely surrounded by water which insures cool injection nozzles. Helical ribs are used in the cylinder jackets to increase the velocity of the cooling water at points near the combustion space and distilled water is used in both jackets.

Low compression of 360 lb. press. and a mean effective pressure of 76 lb. are employed in this engine. Simple flat cylinder heads and pistons have been adopted in conjunction with an arrangement of both penetrating and atomizing fuel sprays especially suited to the combustion chamber. The fuel is injected through two automatic spring-loaded fuel valves in each cylinder head on a controlled pump system. A separate fuel pump is provided for each end of each cylinder and the six pumps which are shown on the left of Fig. 1 are at floor level and close to the control wheel. Both timing and quantity of fuel injected are thus under the immediate control of the attendant.

A special feature of the fuel valves is the arrangement of five holes in the nozzle which form the spray as shown in Fig. 4. The combustion space is annular and four of the jets in each nozzle are drilled to spray horizontally, two on each side of the piston nut or rod

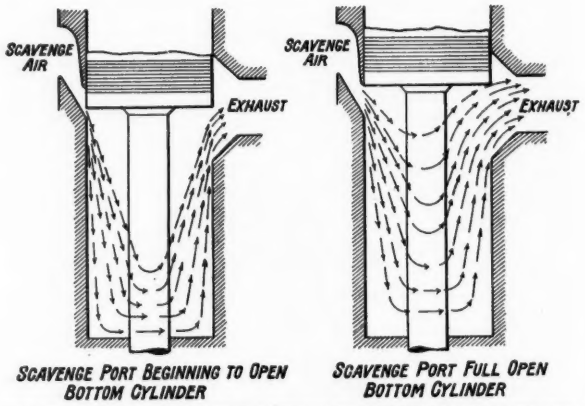


FIG. 3. SCAVENGE PORT ACTION IS DESIGNED TO SWEEP OUT BURNT PRODUCTS FROM CYLINDER IN THOROUGH MANNER

as the case may be. The fifth jet sprays downwards, the hole being formed so as to give the issuing fuel a widely spread rotating movement. The idea is that this downward projecting jet will immediately ignite as it enters the cylinder and will then ignite the horizontal jets which have considerable penetrative power. The fuel pipes connected to the top and bottom of the cylinder are necessarily of different lengths, but the

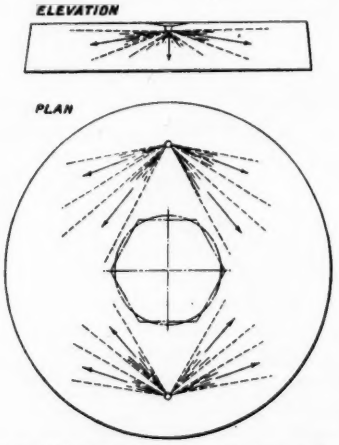


FIG. 4. OIL SPRAY INJECTION IS DESIGNED TO EFFECT THOROUGH MIXTURE AND RAPID FLAME PROPAGATION

timing of the fuel pumps, one of which is provided for each pair of valves, is arranged to effect equal distribution. The lifts of the valves are also adjustable to equalize any difference in delivery between the two fuel valves on the one cylinder head.

The pistons are maintained at a relatively low temperature and a heat resisting steel ring is attached to the cylinder head and allowed to reach a high temperature in order to effect ignition without resort to high compression. This ring, which protects the liner against any action of the fuel sprays in the vicinity of the combustion chamber, serves this purpose better than would a very hot piston head.

Electrical Characteristics *of* AUTO-TRANSFORMERS

SOLUTION OF AUTO-TRANSFORMER PROBLEMS BY VECTORS; CLASSIFICATION INTO GROUPS.

BY R. L. BROWN*

CONSIDERING the auto-transformer from a purely physical point of view, it is a comparatively simple piece of apparatus and, from this angle, it is well understood by operators and engineers dealing with transformers.

When its electrical characteristics are considered, however, there are certain complications which may be introduced which are apparent only to the designer. A better understanding of these complications should be of value especially to those who are specifying and operating such transformers.

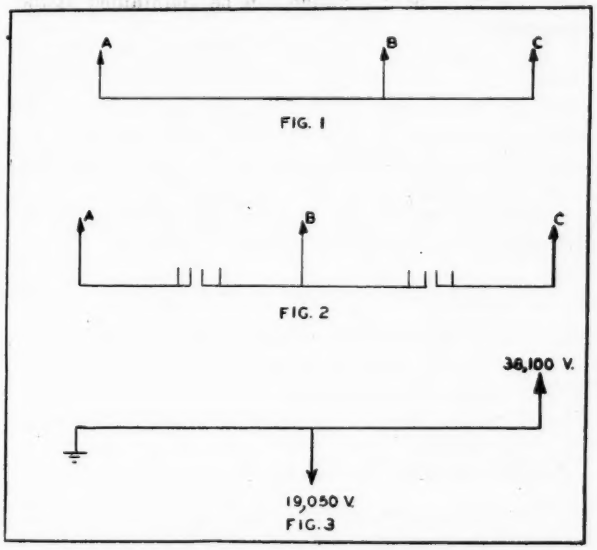


FIG. 1. DIAGRAM OF SIMPLEST FORM OF AUTO-TRANSFORMER
FIG. 2. DIAGRAM SHOWING TAP CONNECTIONS IN THE MIDDLE OF THE WINDING
FIG. 3. AUTO-TRANSFORMER DIAGRAM FOR TWO-TO-ONE RATIO

Some of the complications referred to are the addition of taps in the high or low voltage windings, or both, the addition of a third winding or a combination of these features.

In its simplest form the auto-transformer consists of a single winding AC, Fig. 1, with a tap B.

It is common practice among designers and operating engineers to refer an auto-transformer to the two-winding transformer, which is its equivalent in physical size. This is known as the "kv-a. parts" of the auto. This is for the purpose of determining the physical size only as an auto-transformer is rated at the kv-a. which passes through it.

Referring to Fig. 1, and taking AC as the primary and AB as the secondary, the kv-a. parts may be calculated from the following formula.

$$\text{kv-a. parts} = \frac{BC}{AC} \times \text{kv-a. transformed} \qquad (1)$$

As an example, for a 1000-kv-a. auto-transformer with a voltage ratio of 33,000 to 22,000 v., the kv-a. parts are:

$$1000 \times \frac{33{,}000\text{-}22{,}000}{33{,}000} = 333 \text{ kv-a.}$$

Theoretically this transformer is as large physically as a 333-kv-a. two-winding transformer with the same voltages. Practically, however, this is not quite true as the space factor in the windings and the ratio between iron and copper weights will not usually be as good for the auto-transformer as for a two-winding transformer.

For a 333-kv-a. transformer of either type, the losses are approximately the same. The efficiencies of an auto-transformer are based upon the kv-a. transformer and are therefore much higher than for a two-winding transformer for the same duty. This fact should be kept in mind as well as the saving in first cost and floor space required in applying auto-transformers. There are limitations in auto-transformers, however, which will be brought out later in this discussion, which sometimes make it undesirable to use them in preference to two or three-winding transformers.

TAPS IN AUTO-TRANSFORMERS

It is frequently necessary to place taps in the windings of an auto-transformer to regulate either or both voltages. It is not practicable to place taps adjacent to the line connections for voltages above 22,000. This is due to the fact that extra insulation is used on the turns adjacent to the line and if taps were placed on the ends of the winding this additional padding would be required throughout the tapped section. Furthermore, taps placed adjacent to the line where the most severe voltage stresses obtain, constitute a weakness which may be avoided by placing the taps in the middle of the winding as shown in Fig. 2. When taps are placed in the high voltage end of the winding, B to C in Fig. 2, their effect is just the same as in a two-winding transformer except that the kv-a. parts are increased for over voltage taps.

When it is necessary to regulate the low voltage by taps, however, the high voltage must be compensated for the turns removed or added in the low voltage. In other words, the number of turns in the total winding must not be changed, so when turns are added or subtracted in the low voltage, a like number must be subtracted

*Transformer Engineer, Westinghouse Electric & Mfg. Co.

or added in the high end of the auto. This requires two taps for each tap voltage, one below and one above, the low-voltage line connection. If taps are required in both the high and low voltages of the auto, i.e., if either voltage must be regulated independently of the other, the number of taps may become excessive. It is, of course, possible to change the low voltage by taps without compensating for them in the high-voltage end of the auto. This causes a change in the volts per turn in the transformer, which changes the amount of flux in the core, thus the full effect of the turns cut in or out of the low end of the auto is not realized in voltage change. The percentage change in the low voltage will be the percentage change in turns multiplied by the new

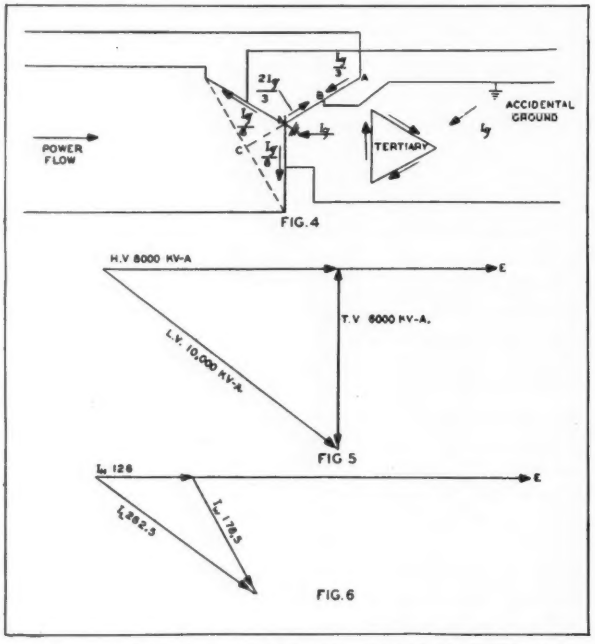


FIG. 4. CURRENT RELATIONS DURING ACCIDENTAL GROUND
FIG. 5. VECTOR DIAGRAM SOLVING TRANSFORMER PROBLEM
FIG. 6. VECTOR DIAGRAM OF CURRENT RELATIONS IN AUTO WINDING

kv-a. parts factor. For example, if 5 per cent of the low voltage turns are cut out in a 2 to 1 auto-transformer, the actual change in the low voltage is:

$$5 \times \frac{100}{195} = 2.56 \text{ per cent}$$

This, of course, is not an economical method of regulating the low voltage and, furthermore, is limited in the range through which it may be applied, due to saturation in the core for under voltage taps.

To obtain an idea of the physical size of the auto-transformer with taps, the highest high voltage, including the compensating taps mentioned above, and the lowest low voltage, should be used in calculating the kv-a. parts, if all the voltages are full capacity. The temperature run should also be made on this connection.

If an auto-transformer has reduced capacity taps, the rating must be decreased more than directly proportional to the voltage if the size of the transformer is not to be increased by these taps. This is due to the fact that the current in the low voltage end of the auto does not vary inversely with the voltage.

Reactance

Another characteristic of the auto-transformer in which it differs radically from the two-winding transformer, is in its inherent reactance.

Referring to Fig. 1, the reactance may be calculated by first considering AB and BC as two separate windings. Having calculated this reactance in the usual manner used for two-winding transformers, it must be multiplied by the kv-a. parts factor, $\frac{(BC)}{(AC)}$ to obtain the effective reactance. This gives the reactance which limits the current on short circuit. This reactance is sometimes low, making it difficult and in some cases impossible to make the transformer self-protecting, i.e., short circuit proof, if voltage can be maintained at its terminals.

Let us take, for example, a 5000-kv-a. auto-transformer with a voltage ratio of 66,000 to 33,000. A two-winding transformer of this voltage and rating would have a reactance of approximately 8 per cent. For a two-to-one auto-transformer with the same design constants, the reactance would be 2 per cent.

In per cent for the two-winding transformer, the reactance can be calculated from the formula:

$$\text{Per Cent Reactance} = K \frac{N^2 I f}{E} \qquad (2)$$

N = No. of turns in one winding (either high or low).
I = Current in that winding.
E = Voltage of that winding.
K = Constant depending upon the physical aspects of the design.
f = frequency.

For the auto-transformer in Fig. 3, assuming the same value of K as above, the number of turns in the high voltage winding above the low voltage line tap is N/2. This gives a reactance between the high voltage end and low voltage of the auto-transformer of ½ that of the two-winding transformer, since E is also one-half of the two-winding value above. When multiplied by the kv-a. parts factor $\frac{(BC)}{(AC)}$ (Fig. 1), this reactance becomes ¼ that of the straight two-winding transformer. In an actual design, however, the number of turns would not be the same for the auto-transformers as for the two-winding transformer, as this would not give an economical ratio between iron and copper weights. For the above auto-transformer, the number of turns would be about 140 per cent of that used for the two-winding transformer, which would make the reactance 4 per cent instead of 2 per cent, assuming the physical constants to remain the same.

From the foregoing example, it may readily be seen that if the high and low voltage are nearly the same, the inherent reactance is necessarily very low if a normal and economical design is used. In fact, if the voltage ratio is small it is usually impossible to brace the transformer sufficiently to withstand short circuits with voltage maintained. It may be necessary, in such

cases, to limit the short circuit current from 15 to 20 times normal by taking into account the external reactance in the lines or, if there is not sufficient of this, by the use of current limiting reactors.

Another feature which should be pointed out here, which makes it objectionable to have a high inherent reactance in an auto-transformer with a low voltage ratio, is the fact that on a short circuit from line to neutral the whole primary voltage is thrown across the high voltage end of the auto between the high voltage line and the low voltage line, i. e., B to C in Fig. 1. This throws a severe voltage stress on this part of the winding. If, however, the resulting current is limited by reactance external to the transformer, this stress is greatly reduced.

Variation of Reactance on Taps

In a two-winding transformer, the variation of reactance on taps is usually negligible. In formula (2) the only factor, the influence of which is not cancelled out on taps, is a slight change in K. This is due to the slight physical change in the windings with a tapped section cut in or out.

In an auto-transformer, however, the reactance changes appreciably on taps. Taking, for example, the 2 to 1 auto-transformer referred to previously with 4 per cent normal reactance, if there is a 10 per cent over voltage tap range in the high voltage, the reactance will be increased in the ratio of the square of the ratio of the new kv-a. parts to the old, or will be:

$$\left(\frac{0.545}{0.5}\right)^2 \times 4 = 4.76 \text{ per cent}$$

If there were a 10 per cent under voltage tap in the high voltage, the reactance on this tap would be:

$$\left(\frac{0.444}{0.5}\right)^2 \times 4 = 3.16 \text{ per cent}$$

Since the reactance of an auto-transformer varies so widely on taps, it is not practicable to make an auto-transformer parallel with a two-winding transformer except at one voltage ratio, without the use of external reactors or balance coils.

Auto-Transformers with a Third Winding

Since auto-transformers for power service are usually, if not always, star-star connected with the neutral grounded, it is necessary, in all single-phase units and in three-phase shell type and large three-phase core-type transformers, to supply a tertiary winding to carry the third harmonic in the exciting current.

If this winding were required to carry only the third harmonic currents, it could be small and would have little influence on the transformer design. Due to the fact, however, that it must carry the kv-a. which flows to ground when a line becomes grounded, experience has shown that it is necessary to make this winding with a capacity of about 35 per cent of the kv-a. parts of the transformer. The way in which the tertiary functions in allowing the ground current to flow in a two-to-one auto-transformer may be seen from Fig. 4.

When a low voltage line becomes grounded, the currents flow as shown by the arrows. If there were no tertiary, there would be no counteracting ampere turns and the currents would be limited by the magnetizing impedance of the transformer, which, of course, is extremely high. With the tertiary winding connected in delta, a path is provided for the counteracting ampere turns. A study of Fig. 4 will show that the ampere turns add up to zero, which is essential if low impedance to the flow of ground current is desired. If the tertiary circuit is opened, currents will tend to flow in the auto windings but will be limited by the magnetizing impedance of the transformer. If the transformer in Fig. 4 were other than two-to-one ratio, the distribution of current would be changed but direction of flow would be the same. The currents which actually flow are determined by the ratio of the voltage shorted to the high voltage single-phase voltage in the same direction. In Fig. 4 this ratio is BN to AC, or one-to-three. Therefore, only ⅓ as much current flows in the high voltage as in the ground. The thermal capacity of the tertiary winding required to carry these currents determines its rating. The amount of ground current which flows is determined by the reactance of the tertiary to the other windings.

Since it is necessary in most cases to have a tertiary as pointed out above, it is often desirable to make the winding so that a load may be taken from it. This load may be for local distribution but it is more often used for supplying a synchronous condenser for power factor correction and voltage control.

When the tertiary is added, the kv-a. parts can no longer be calculated by Formula 1. The actual kv.a. rating of the various windings and the method of loading must be taken into account. Let us take as an example the following single-phase transformer.

110-kv. star high voltage auto winding... 8000 kv-a.
66-kv. star low voltage auto winding....10,000 kv-a.
13,200-v. delta tertiary winding..... 6000 kv-a.

The conditions of loading are such that all windings may be loaded simultaneously at their full rating. Also 6000 kv-a. may be transferred from the lower voltage winding to the tertiary with the high voltage winding idle.

The vector diagram for the loads is shown in Fig. 5. This assumes the tertiary load to have a power factor of zero leading. This is not obtained in practice, due to the losses in the condenser, but for all practical purposes may be taken as zero. The 66-kv. winding is loaded at 80 per cent lagging power factor.

To find the currents which flow in the auto winding we may draw another diagram, Fig. 6, using the line currents in the auto-winding. Since the current in the low voltage end of the auto is the vector difference between the low voltage line and high voltage line currents, it is only necessary to find the vector difference between these two currents to find the low voltage winding current. This may be done graphically by drawing Fig. 6 to scale and measuring Iw, or by complex quantities. An illustration of this latter method follows, using the following symbols:

I_H = Current in high voltage line
I_L = Current in low voltage line
I_W = Current in low end of auto winding
$j = \sqrt{-1}$

(1) $I_H = 126 + jo$
(2) $I_L = 210 - j\ 157.5$

Subtracting (1) from (2)

$I_W = 84 - j\ 157.5 = 178.5$ amp.

This is the maximum current this winding will carry if there are no taps. We may now calculate the kv-a. parts of the transformer.

The kv-a. of the high voltage end of the auto = 25,400 × 126	=	3200 kv-a.
The kv-a. of the low voltage end of the auto = 38,100 × 178.5	=	7100 kv-a.
The kv-a. of the tertiary	=	6000 kv-a.
Total ÷ 2	=	8150 kv-a.

The equivalent two-winding kv-a. is 8150. As pointed out before, this is not quite true due to the high voltage class of the low voltage winding and the poorer

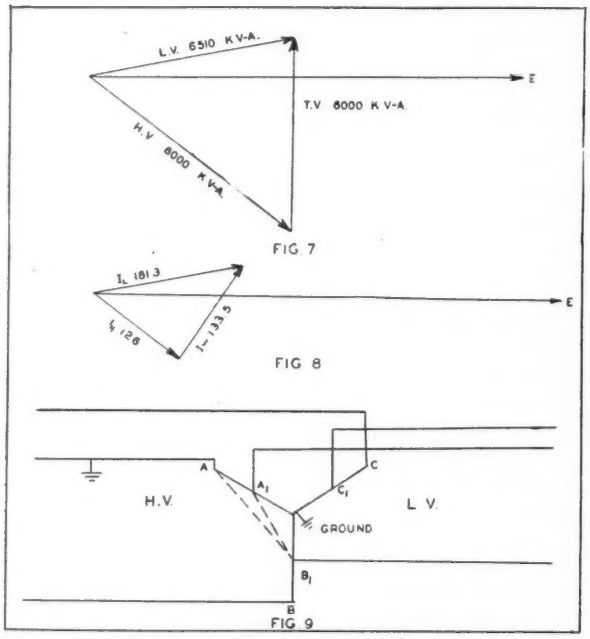


FIG. 7. VECTOR DIAGRAM FOR AUTO-TRANSFORMER STEPPING UP FROM 66 TO 110 KV.
FIG. 8. CURRENT RELATIONS IN STEP-UP AUTO-TRANSFORMER
FIG. 9. STAR CONNECTED AUTO-TRANSFORMER DIAGRAM WITH NEUTRAL GROUNDED

space factor due to the fact that there are three windings instead of two.

If these transformers were stepping up from 66 to 110 kv. with the condenser operating, the vector diagram of the kv-a. would be as shown in Fig. 7, assuming that a load of 8000 kv-a. is taken from the high voltage at 80 per cent power factor lagging and 6000 kv-a. at a power factor of zero leading from the tertiary.

The currents may be obtained as shown in Fig. 8.

$$I_L = 178.2 + j\ 33.4$$
$$I_H = 100.8 - j\ 75.6$$
$$I_W = 77.4 + j\ 109 = (133.5 \text{ amp.})$$

It may be seen that the condition of loading greatly affects the size of an auto-transformer with a tertiary winding. If the auto-transformer load is at a lagging power factor and the tertiary leading, it will usually be found that the greatest current in the low end of the auto occurs with the auto-transformer stepping down. Due to the effect of the tertiary load on the cross section of conductor required for the low voltage winding, as was pointed out, it is essential that the designer know the direction of power flow, i. e., whether the transformer is to be used for stepping down or stepping up. He must also know the range in power factor for the auto winding load and the corresponding simultaneous loads and power factors for the tertiary.

If the kv-a. rating of the tertiary is greater than the kv-a. parts of the auto winding, it is necessary to know whether or not the full tertiary rating is to be supplied from the low voltage with the high voltage idle, as this may require that the low voltage conductor cross section be increased.

If an auto with a tertiary is loaded on two windings simultaneously at the same power factors, the arithmetic sum of the loads must not exceed the rating of the third winding.

Insulation

Auto-transformers for power purposes are usually, if not always, connected star with the neutral grounded. There are good reasons for this practice. In an auto-transformer, two circuits of different voltages are tied together by a metallic connection; therefore, unless the potential of the two lines above ground is fixed, the lower voltage line is subject to the over voltage disturbances of the higher voltage circuit. If, however, the neutral is permanently and solidly grounded, as shown in Fig. 9, such disturbances will not affect the lower voltage line and its connected apparatus any more than for a two winding transformer.

If the neutral of the star-star connected auto-transformer were not grounded and a high voltage line A became grounded, it may readily be seen that the actual voltage of B_1 above ground would be AB_1, whereas the insulation of the low voltage line and its connected apparatus is based upon a voltage of A_1B_1 above ground. With the neutral solidly grounded, a line to ground short circuits cannot produce any such over voltages except within the transformer itself, as pointed out under the discussion of reactance.

Since, for these reasons, the neutral must be solidly grounded, the use of an induced voltage test to demonstrate the insulation strength of the transformer is desirable from an economic as well as operating consideration. This applies to those transformers in which the high line voltage is 88 kv. or above. For voltages below this, the induced test may be used but little if any saving can be effected.

The test employed consists usually of inducing 2.73 times the line to neutral voltage in each winding for a period of at least 7200 cycles. The reason for such a test is obvious. A large part of the insulation in a transformer is required in insulating the windings from ground. If a straight disruptive test is used, the whole winding must be insul ted for the full test above ground. This is obviously unnecessary since in service the potential above ground tapers from the grounded end up to the line end. Therefore, when a grounded neutral transformer is given a disruptive test, the factor of safety for the part of the winding nearest ground is several times that adjacent to the line. With the induced test, the factor of safety may be kept practically constant throughout the winding, since the various groups of coils in the winding may be insulated for their actual voltage above ground. The amount of insulation be-

tween coils and turns for the group of coils connected to the line is not affected by the induced test. For the body and ground groups, this insulation is reduced somewhat in keeping with the less severe voltages encountered, in service with the neutral grounded.

Summary

Auto-transformers may be classified roughly into three groups: (1) Those having no tertiary windings, (2) those having tertiaries for third harmonics and stabilizing the neutral only, and (3), those having tertiaries for power purposes.

Any of these classes may be complicated by the addition of taps in the auto winding.

In group (1) fall the small three-phase core-type auto-transformers where a tertiary is not required, also small low voltage delta connected autos. It is usually not desirable to connect large auto-transformers, designed for power duty, in delta due to the phase displacement resulting, as well as the possibility of high voltages being impressed on low voltage connected apparatus if a high voltage line becomes grounded.

The "kv-a.-parts," or the equivalent two-winding transformer, are found by dividing the difference between the high and low voltages by the high voltage and this factor multiplied by the kv-a. transformed.

Due to the fact that taps cannot be placed adjacent to the line for the higher voltages, it is necessary to compensate the high voltage of the auto for taps in the low voltage. This requires two taps for each tap voltage in the low voltage, one below and one above the low voltage line lead.

In group (2) fall the large three-phase core or shell-type autos as well as all single-phase autos where it is necessary to suppress the third harmonic voltages and stabilize the neutral. The location of the tertiary with respect to the other windings and the leakage reactance between it and the auto winding is not of great importance. It should, however, be low enough to allow ground currents of sufficient magnitude to flow to operate relays, etc. This function of the tertiary requires a capacity of winding equal to about 35 per cent of the power windings.

The kv-a. parts for the auto with a tertiary are obtained as for class 1 except the tertiary winding capacity divided by 2, i. e., put on a two winding transformer basis, is added. It should be kept in mind that the methods given for determining the kv-a. parts of an auto are approximate and are to be used for estimating purposes only. As may be seen from this discussion, there are many factors which influence the physical size of an auto-transformer to a greater extent than a two or three-winding transformer. Some of these factors, such as the requirement of constant per cent reactance over a range in voltage ratios, may make the use of a two-winding transformer more economical. The effect of any special requirements should be studied before applying an auto-transformer.

In group (3) fall the auto-transformers which have a tertiary winding both for suppressing third harmonics and supplying a load. The most common use for the tertiary is for supplying a synchronous condenser for power factor and voltage control.

For this group the reactance between the other windings and tertiary is a matter of importance. The ideal arrangement is one which gives approximately equal reactances between all windings at a common kv-a. This is usually impracticable for an auto-transformer.

For small kv-a. parts, that is, where the high and low voltages are nearly the same value, it is uneconomical to make the transformer self-protecting. In such cases, it may be necessary to brace the transformer windings to withstand short circuit currents of 20 to 25 times normal. The external circuits will usually add sufficient reactance to keep the short circuit current within these values.

The kv-a. parts for this group are obtained by calculating the maximum currents which flow in each of the windings for the conditions of loading specified. The power factor of the loads must be considered in obtaining the current in the low end of the auto-transformer. The currents thus obtained are multiplied by the maximum voltage of that winding, and the sum of these kv-a.'s divided by 2 to give the kv-a. parts.

It is important that the conditions of loading be definitely defined for transformers in this group.

High voltage auto-transformers must be connected in star with the neutral solidly grounded. This must be done to protect the low voltage circuits from over voltages. These transformers should be given an induced test rather than a disruptive test, as this permits distributing the insulation so that the factor of safety over volages encountered in service is nearly constant throughout the windings.

Vacation Precautions

Police Russell warns those who are going on vacation to notify the milkman and newsboy so that the clutter of milk bottles and unfolded newspapers around the door may not mark the house as a desirable place for yegg men to visit on some dark night.

Failure of the vacationist to notify the post office where to send his mail may mean that mail of great importance is held until he returns or is returned to writer.

This is also vacation time in the post office. Under the law, letter carriers must be given 15 days' vacation but mail must move and deliveries must be made by a substitute who is sometimes limited in experience and who may be unfamiliar with the district and those who live on it. Under the best circumstances, delivery is not an easy task and, when a substitute is sent out on the district, delivery is often impossible, because of the failure of patrons provide a proper receptacle for their mail, with the name of the resident plainly shown above the box.

It is particularly desirable that the names of transient visitors who expect mail shall be placed over the box during the period of their stay, or that their mail be addressed in care of the person whose name is on the box. Much can be done to expedite delivery and make a hard grinding task easier for the carrier by furnishing a proper mail box with the names plainly shown over it.

Iowa Southern Utilities Co. has ordered three 500-hp. water-tube boilers, costing about $50,000 from the Murray Iron Works Co., Burlington, Iowa, for early delivery. Two of the boilers will be delivered to the Ottumwa plant and the other to Centerville.

Electrical Equipment of Steel Rolling Mills

TOTAL POWER CONSUMPTION FROM BLOOMING MILL RUNOUT TO COAL STORAGE IS 45.6 KW-HR. PER T. OF STEEL ROLLED. BY J. B. INK*

RECENTLY the American Rolling Mill Co. at Middletown, Ohio, placed in service a continuous bar plate and hot strip mill. Figure 1 shows general arrangement of mill and the single line diagram, Fig. 2, shows the principal electrical connections. The new mill produces ingot iron and various grades of steel strip in gages down to 0.093 in. and widths up to 48 in., also plates ¼ in. thick and 60 in. wide in 75-ft. lengths. These products are rolled from 6 in. thick slabs, 39 in. long, and of the width required in the finished product. For ease in handling and storing, the strip steel is coiled on leaving the last stand of the hot strip mill.

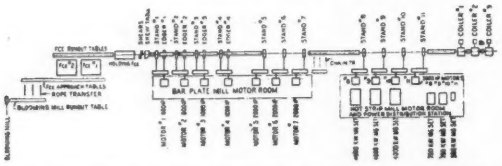


FIG. 1. GENERAL ARRANGEMENT OF BAR PLATE AND HOT STRIP MILLS

Of the 11 stands, the first 7 constitute the "bar mill" and normally reduce the sheet to about ⅜ in. thickness. The last 4 stands are the hot strip mill. Between stands 7 and 8 are runout table, transfer, and bar piler for taking off sheet bar or other heavy gage product.

When it enters No. 1 stand the slab is 39 in. long. This length increases as the piece progresses through the successive stands. When the length has increased to about 20 ft., as it does in No. 4 stand, it is about equal to the minimum spacing between stands possible with this type mill. Thus, the following stands, to be economically spaced both for conservation of floor area and heat, must be on centers less than the length of the piece, with the result that the piece, after leaving No. 4, is in two or more stands at the same time. This requires close control of speed, as any change in speed or draft in one mill must be accomplished by a corresponding change in the other stands in the train. In rolling wide strip, wearing of rolls makes frequent changes in draft necessary.

From the foregoing it follows that stands No. 1 to No. 4 are independent as regards speed while No. 5 to No. 7 and No. 8 to No. 11 are inter-dependent. The independent stands No. 1 to No. 4 are each driven by a wound secondary induction motor and are equipped with flywheels. The motor horsepower varies from ¼ to ½ the total rolling horsepower, the balance of the rolling energy between taken from the flywheel. The output of the motor is limited by automatic liquid slip regulators which introduce resistance in motor secondary as the motor primary current increases and so permits the flywheel to give up stored energy.

Motors driving stands 1 to 4 and their control are housed in a ventilated brick and steel motor room. They are equipped with thermocouples in primary windings for checking temperature, thermostatic relays in bearings, and space heaters to prevent "sweating" during shutdown. Primary winding is mica insulated and coil ends are braced to insulated steel ring supported from stator frame to resist shocks incident to the service. These motors, all 6600-v., 3-phase, 60-cycle, 40 deg. C. rise, are controlled from the bar plate mill pulpit, which is similar to hot strip mill pulpit.

Motor primary is connected to main bus by Westinghouse type OE6 oil circuit breaker. For plugging, there is provided a Westinghouse type B2 breaker which connects the motor to reverse bus. The reverse bus is connected to main bus by an OE6 breaker. The forward

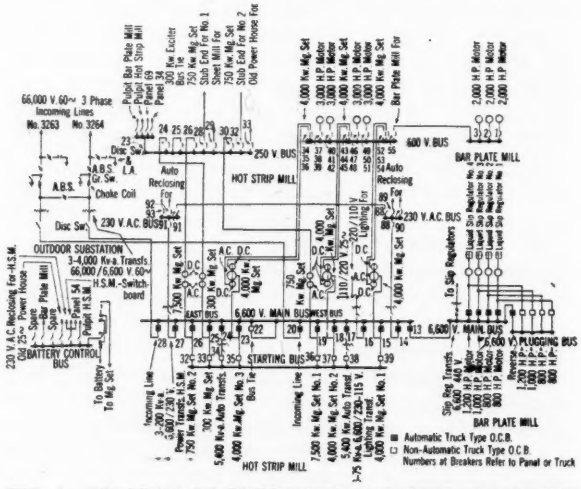


FIG. 2. DIAGRAM OF ELECTRICAL CIRCUITS IN ROLLING MILL

breaker and reverse bus breaker are automatic on overload and undervoltage. Thus one automatic breaker gives undervoltage and overload reverse protection to the four motors. Oil circuit breakers are truck type having all hot parts enclosed. Forward and reverse breakers are interlocked electrically and mechanically to prevent simultaneous closing.

Motor secondaries are connected to the bottom electrodes of liquid slip regulators, a form of water rheostat in which the electrolite is a solution of sodium carbonate. Three top movable electrodes are connected together and the distance between top and bottom electrodes is varied by the action of a torque motor energized from current transformers in the motor primary circuit. The torque of the torque motor is proportional to the square of the primary current so that it is very sensitive to change in load. When the load exceeds a pre-determined amount fixed by counterweights, the torque motor raises the electrodes, thus increasing the secondary resistance and reducing torque due to primary current to a point where the balance between weight of electrodes and motor torque is reëstablished. Figure 3 shows a graphic wattmeter record of input to the a.c. motors. Super-

*American Rolling Mills Co., Middletown, O. From a paper presented before the A.I.E.E.

imposed upon these curves of motor input are shown the actual rolling horsepower. Note that the motor furnishes directly only a small part of the energy used in rolling, the flywheel supplying the major portion.

Interdependent stands 5 to 11 inclusive, all 4-high 56 in., working rolls 18 in. diameter, backing up rolls 36 in. diameter, roller bearings, are driven by 600-v. d.c. adjustable speed motors. Due to the necessity for close speed regulation, and the fact that the piece is in the stand a considerable length of time, flywheels are impracticable on these stands. The motors, therefore, must provide maximum rolling torque.

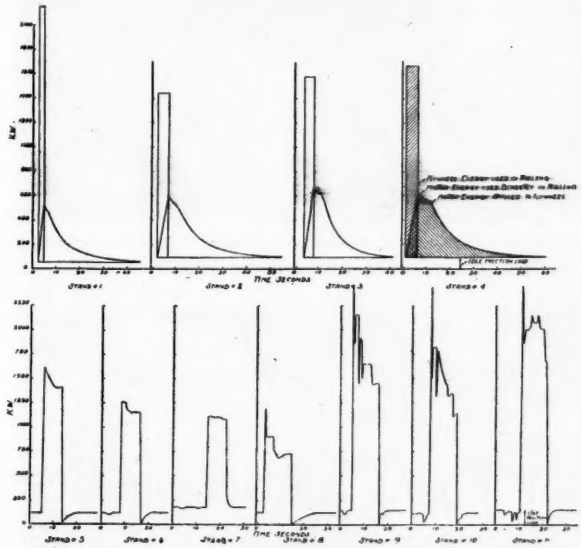


FIG. 3. INPUT TO MILL MOTORS

They are heavy duty type with low pedestal bearings and fabricated structural steel bases. The 3000-hp. motors, being low speed, require forced air ventilation. Motors are equipped with bearing thermostatic relays, over speed devices, and heaters to prevent sweating during shut down. To each shaft is geared a speed indicating magneto. These motors are constant horsepower, speed adjustable by field control. Motors are compounded by use of series exciters. The series exciters consist of generators driven by 5-hp. induction motors. The generator field is excited by ¾ turn of the main motor armature circuit, so that the voltage generated is proportional to the input to the main motor. The generator circuit supplies a series field winding similar to the shunt winding on the main motors. Shunt field excitation is at 250 volts.

Compounding is adjusted to different motor speeds by a rheostat in the series exciter circuit. This rheostat is on the same shaft as the main shunt field rheostat so it is automatically adjusted with the main shunt field. A speed regulation of ½ per cent was obtained in test of these motors.

To avoid readjustment of rheostat after a shutdown, a resetting face plate is provided on shunt field rheostat so that by its manipulation full field for starting may be secured and the main rheostat setting not disturbed. In addition to the main rheostats which are motor operated, a hand operated fine adjustment rheostat is mounted in the operating pulpit.

The d.c. motors are entirely controlled from the operator's pulpit, except that emergency stop control switches are provided in motor rooms. They are started from the 600-v. d.c. bus through series resistance and contactors using current limit accelerating relays. Dynamic braking is used in stopping mills.

Motors are protected against overload, low voltage, field failure and over speed. Each motor control panel is connected to main bus through disconnects so that panels may be isolated for repair without killing the main bus.

Mill auxiliaries are with a few exceptions motor operated. Squirrel-cage 220-v. induction type motors with magnetic cross line starters are used for all constant speed continuous duty applications such as fans, pumps, and chain tables between mills. These motors are in sizes from 2 to 75 hp. They are standard sleeve bearing motors with drip proof covers. The cross-line starters provide low-voltage protection and have thermal overload relays.

For intermittent duty, on loads having high starting torque and requiring quick acceleration, 250-v. d.c. mill type series or compound motors are used. This includes all cranes, transfer tables, roller tables, except hot strip

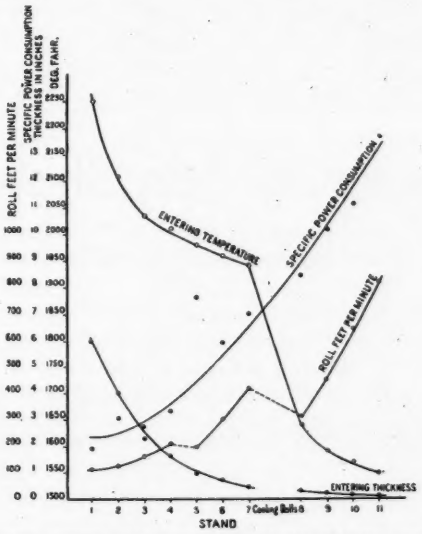


FIG. 4. RELATIVE VALUES, AT EACH STAND OF ROLL SPEED, POWER CONSUMPTION, THICKNESS OF METAL AND ENTERING TEMPERATURE

run-out table, furnace pushers, pinch rolls, and screw downs. The controls for these motors are all of the magnetic definite time limit acceleration type. The control panels excepting for cranes are arranged in groups in dust tight brick rooms. With each group is a spare panel which may be substituted for any control panel in the group by manipulating transfer switches.

An unusual feature of the new mill is the equipment for handling the strip as it leaves the mill. The metal is carried from last stand to coilers by a roller table in which each roll is direct coupled to an individual motor. These motors are 3-phase, 88/220 v., totally enclosed squirrel-cage type operating on variable frequency from 24 to 60 cycles, rated from 0.4 to 1 hp., speed range 190 to 480 rev. per min. The rolls are 10 in. diameter so that the speed of the table is from 500 to 1260 ft. per min. The motors are grouped on three circuits so that

one circuit may be opened without interrupting operation of the table. When one circuit is opened every third motor stops, the other two being sufficient to handle the material.

Variable frequency current for the runout table is furnished by a 24/60-kv-a., 24/60-cycle, 88/220-v. generator driven by an adjustable speed direct-current motor. The table is started from the 220-v., 60-cycle mill circuit. With this arrangement, it is only necessary to provide a variable frequency motor generator of sufficient capacity to run the table. Since the starting current is four or five times running current and has a low lagging power factor, a much larger generator would be required to maintain voltage in starting than is required for running only.

Three coilers take the strip steel from the last stand of the mill and form it into a coil about 30 in. in diameter. The sheet is at a red heat when it enters the coiler and is cooled by water before being discharged. The coiler is driven by a 75-hp. adjustable speed d.c. motor which drives the coiler rollers through multiple spindle gears. The rollers bear on the surface of the coil and as the coil grows are expanded by a cam driven by a 5-hp. adjustable speed motor. The strip steel is forced into the coiler by a pinch roll. The machine is started automatically when the strip completes a circuit from ground to the surface of an insulated roller.

About 30 sec. is required to coil, cool, and discharge a strip of 12-gage steel 180 ft. long and 48 in. wide.

Power required to roll steel sheets varies with temperature, per cent reduction, speed of rolling, kind of material, and diameter of roll. It is probable that a large part of the input to the old type mill with brass bearings is consumed in friction in the bearings. This fact is demonstrated in comparative tests made on the four high stands of the mill herein described, which are equipped with roller bearings, and another mill making similar product and having brass bearings. In these tests, it was found that the specific power consumption (horsepower-seconds per cubic inch of metal displaced) in the brass bearing mills was much higher than in the roller bearing mill. This difference increases as the temperature of the piece falls and bearing pressure increases.

Curves of Fig. 4 illustrate the relative value of different variables at each stand of the mill. The drop in temperature between stands 7 and 8 represents the critical range of ingot iron, between 1922 deg. F. and 1562 deg. F., in which range the material may not be rolled.

From the test data, the power consumption per ton of steel rolled is 32 kw-hr., to which must be added the idle friction of mills which make total 40.3 kw-hr. per ton, with a production of 150 t. per hr. To this must be added the power consumption of various mill auxiliaries amounting to about 800 kw-hr. per hour, making a total of 45.6 kw-hr. per t. from blooming mill runout to coil storage.

Paper Models Show Motor Fan Characteristics

DIFFERENT TYPES OF FANS USED FOR VENTILATING INDUSTRIAL MOTORS ARE CHECKED INEXPENSIVELY BY TESTS WITH PAPER MODELS AND INK. BY H. N. BLACKMON*

PAPER MODELS, simulating the sturdy cast-iron centrifugal blowers ordinarily used to ventilate industrial motors, give a quick, accurate and inexpensive check of comparative characteristics of different types of fans. Colored ink, placed in the inlet air, traces graphically the air distribution over the various parts of the blade. A neon lamp, flashing once each revolution of the blower, shows the rigidity of the separate blades during test. An electrical dynamometer and balance arm measure the torque expended and an alcohol manometer indicates the pressure created by the revolving blower.

Electric motors can do more work if kept cool. Industrial motors run in either direction and necessarily have blowers with straight radial blades, usually of cast iron and of fairly heavy sections. Such blowers are inherently inefficient and of low capacity. Comparison of the action of the various paper models tells which type of centrifugal radial blower is best fitted to cool electric motors.

*General Engineer, Westinghouse Electric & Manufacturing Co.

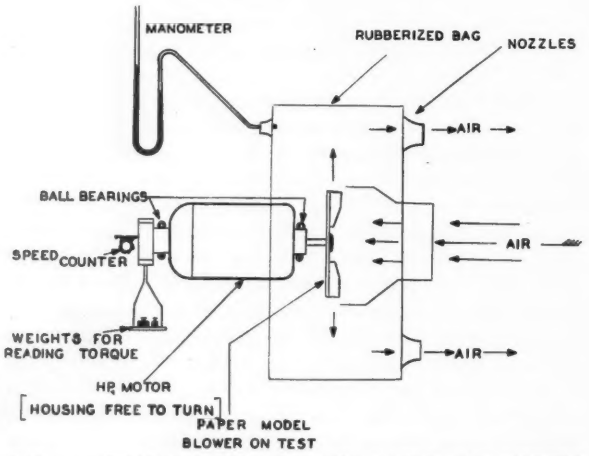


FIG. 1. APPARATUS FOR TESTING PAPER FAN MODELS

CONSTRUCTION OF THE PAPER MODELS

These models differ by presence and absence of rotating shroud rings, number of blades, cross-section of blade, and shape of blade. Models have a diameter of 11 in. and a blade width of 1 in. Each blade is made from ordinary 2½-mil (0.0025 in.) paper, cut and folded to shape; then this hollow box is inverted and glued in place on a flat disc of 0.0025-in. paper which forms the hub of the fan. At rounded or irregular corners, the flaps are fringed before pasting, to give a smooth fit. The paper blades are accurately spaced so that a stroboscope can be successfully used to watch the individual blades at work. Irregular spacing produces a blurred image under the winking stare of the neon lamp.

About 25 models, all of 11-in. diameter, have been tested. A few of the sizes and shapes are given below.

Number of Blades	Blade Cross Section	Blade Size	R.P.M.
14	Square ¼ in.	1 by 1¾ in.	1800
14	Wedge ¼ in.	1 by 3⅞ in.	1800
36	Round ¼ in.	1 by 3⅞ in.	1800

Method of Testing

The testing apparatus is shown in Fig. 1. A ¼-hp., shunt-wound, adjustable-speed motor drives the paper

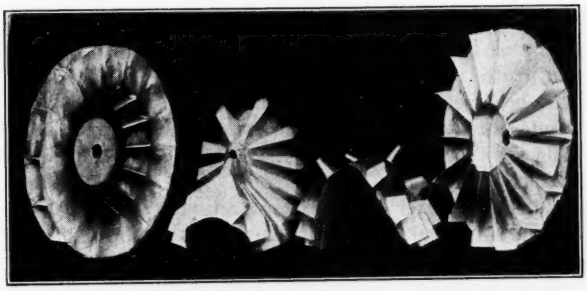


FIG. 2. CONSTRUCTION DETAILS OF SOME OF THE PAPER MODELS

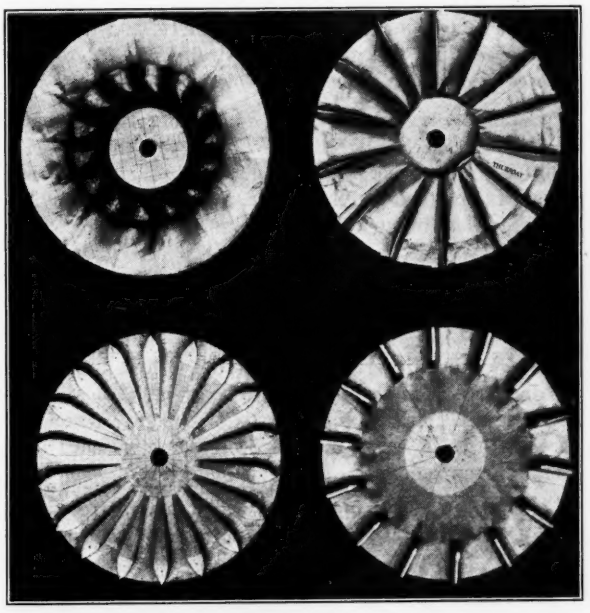


FIG. 3. ANOTHER VIEW OF THE MODELS SHOWN IN FIG. 2

model at any desired speed up to 3000 r.p.m. Ball bearings support the motor housing which acts as a dynamometer; the torque is measured by a balance arm attached to the motor housing and weights, while four weak coil springs serve as flexible power leads to the motor. A tiny shaft extension drives a counter for accurately measuring the speed.

The models rotate inside a large rubberized bag, representing a motor housing. Air enters axially, passes the blower and exhausts through a number of nozzles. Pressure inside the bag is measured by an alcohol manometer.

During a test run, black ink placed in the entering air spreads over the side of the blades showing air distribution and shock load of the air. If the fan is reversed, red ink in the in-going air leaves its trace on the other side of each blower blade, which tells a graphic story after the blower is removed from test. Allowance must be made, of course, for the higher inertia of the ink particles as compared with that of air.

Centrifugal radial blowers, to be fabricated instead of cast, are studied by using models made of $\frac{3}{32}$-in. cardboard. Here the stiff sheet is comparable to the thin structural metal which is welded to make the actual blower.

This simple and economical method of comparing centrifugal blowers is giving practical results.

Piping for Power and Heating Plants

Correction of Diagram and Text

IN THE book on this subject of the Power Plant Engineering Handbooks, it has been discovered that there is a drafting error in the diagram for loss of pressure in a pipe on p. 71. Herewith is a corrected

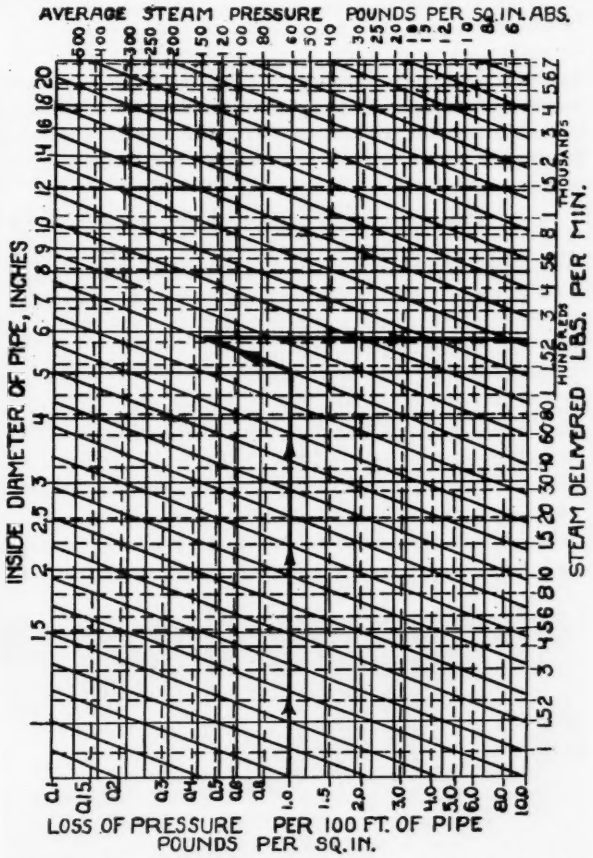

AVERAGE STEAM PRESSURE POUNDS PER SQ. IN. ABS.
INSIDE DIAMETER OF PIPE, INCHES
STEAM DELIVERED LBS. PER MIN.
HUNDREDS
THOUSANDS
LOSS OF PRESSURE PER 100 FT. OF PIPE
POUNDS PER SQ. IN.

diagram which should be cut out and pasted over the one in the book. It will be noted that the steam delivered should be 210 lb. in the problem on p. 71, instead of 66 lb.

Also, in the formula for flow of steam at the bottom of p. 70, the number in the numerator of the term in parenthesis should read 3.6.

At the bottom of p. 91, last line, it should read "at 35 lb. in an 8-in. pipe, etc.," instead of 6-in. pipe.

Readers having the book on Piping should make these corrections in their copies.

This Enviable Record *of* Efficient Service Should Encourage Industrial Plants

FOR 25 YR. THE SECURITY MUTUAL POWER PLANT, BY LOW MAINTENANCE COSTS AND HIGH OPERATING EFFICIENCY HAS JUSTIFIED ITS INSTALLATION

INSTALLING a power plant in the face of severe competition from purchased power, operating that plant 25 yr. in the face of this same competition and not only making the plant justify itself but show an estimated profit of some $8000 a year over purchased power is the enviable record of Chief Engineer Asa P. Hyde, of the Security Mutual Life Insurance Co. of Binghamton, N. Y.

In 1904, when he arrived to take charge of the plant, brick partitions for the installation and isolation of transformers were being laid, and motors, all of the a.c. type, had been purchased. Convinced of the advantages and economy of making power in a private plant and utilizing the exhaust steam for heating purposes, he persuaded the company to install direct-current generating equipment.

Since that time, he has operated the plant, built up a large and profitable outside heating and power load and, most remarkable of all, has kept his plant in step with power plant progress by replacement of old equipment with new when such changes were justified.

Competition has been keen, a factor which keeps the force continually looking for new ways of lowering maintenance and increasing the operating efficiency. Mr. Hyde says, "We have serious competition . . . this is nothing new but dates back to the beginning . . . we have always had it and in a way it has been and is good for us, as it keeps us digging in."

Just how they have been "digging in" is perhaps best illustrated by Fig. 1, which shows the brickwork and grates in one of the boilers after 22 yr. of service. This boiler is one of two 125 lb. gage, 78 in. by 20 ft. Pennsylvania Boiler Works horizontal return tubular boilers (with 86 4-in. tubes), set 4 ft. above McClave-Brooks 52.5 sq. ft. shaking grates. The boilers, Fig. 2, are set in a battery with a third return. Natural draft is used in normal operation but an 18-in. Coe steam-driven blower, so arranged that it can be used on either boiler, is installed for emergency operation. In 1927 the boilers were retubed, not as a necessity but as a matter of precaution. The condition of the boilers was such that the insurance company did not lower the allowable pressure in spite of their 22 yr. of service. At this time, the rear end of the grates were dropped 8 in. to give greater combustion space.

Complete record of boiler room operation is kept. Coal, a mixture of D. L. & W. rice and barley with about ⅛ soft slack or, just enough to burn the ash closer, is weighed before firing. Ash is also weighed and recorded in an adjacent column with the coal so that the percentage can be readily calculated daily.

Feedwater is measured by a Gamon turbine meter and heated to 210-212 deg. F. in a Webster 350-hp. open heater, the evaporation per lb. of coal ranging from 8 to 10. Other instruments include Brown recording thermometers for the boiler feedwater and for the flue gas temperatures, Uehling Apex CO_2 meter, Ellison differential draft gage and Ashton back-pressure and boiler-pressure gages.

So well is the firing and damper control regulated that 115 lb. pressure is closely maintained with an up-

FIG. 1. CONDITION OF THE FURNACE AND GRATES AFTER 21 YEARS OF SERVICE WITHOUT REPLACEMENT

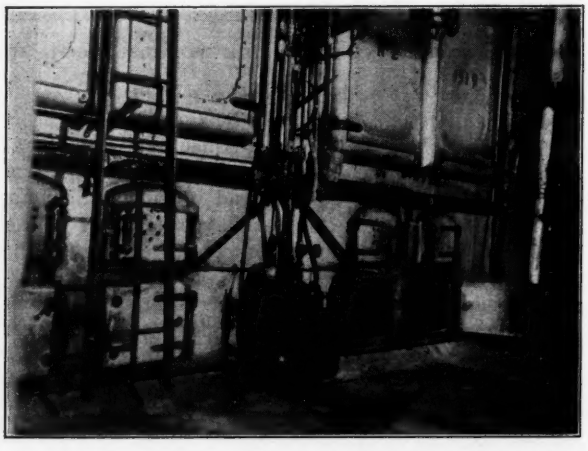


FIG. 2. NATURAL DRAFT IS NORMALLY USED BUT A BLOWER IS PROVIDED FOR EMERGENCIES

take temperature seldom exceeding 450 deg. F. CO_2 is ordinarily held at 13 to 14 per cent.

Detailed Directions for Firing

This efficient operation of the boiler room is due largely to the careful instruction and training given firemen. A copy of directions and instructions follow:

1. Always fire alternately and as lightly as possible, depending on the load being carried. When firing alternately, the fresh fuel added to the fire liberates a large amount of gas which is ignited by the bright fire on the other side and is burned. This gives us the best results as otherwise it goes up the stack a dead waste. By lightly we mean do not load the fire down—four to six scoops full, not heaped, is enough for one side.
2. Fire so that it will not be necessary to use the leveling bar, which is a lazy fireman's tool.
3. Keep the fire level, slightly thicker at the rear and rounded up at the side walls and in the corners. This is important as a thin fire or spots allow too much air to pass through it, dead spots or corners the same. Too thick a spot or clinker are also bad as they do not give enough air.
4. Fire only when needed, not when it is convenient.
5. Always trim the fire at the front, keeping it off the dead plate. Never allow fire burning on the plate. We did run the same arch bricks, dead plates and door linings for over 20 years with careful watching and care.
6. Try to handle the fire so that the main damper is kept closed and the hand damper as close as it is practical, continually adjusting it to suit the fire conditions. By the careful watching of the dampers the uptake gas temperatures can be kept down. This is a saving. Watch the steam chart, CO_2 and the uptake recorders. They can tell you a great deal and give you real help.
7. Water level and steam pressure should be as regular as possible, the blowing of the tubes and the boiler carefully and regularly and thoroughly done on each 8-hr. shift.
8. Practice handling the scoop so that quickly and evenly the fuel is spread over the entire surface, trim the dead plate and close the door. Every time the doors are opened, it is a loss.
9. Carry a fire in depth sufficient to carry the load, deeper with a heavy load. Vary this to suit the conditions. You cannot always do today as you did yesterday or before. Use your head.
10. Cleaning—Don't clean too close. If bright live fire is run through the grate, it is needless waste and live fire dropped on the grate will certainly ruin it, besides causing clinker troubles. Protect the grate always by leaving a film of ash on it.
11. Neatness—Be neat about the plant and your work, each doing not alone his own part but all that he can for the plant as a whole.

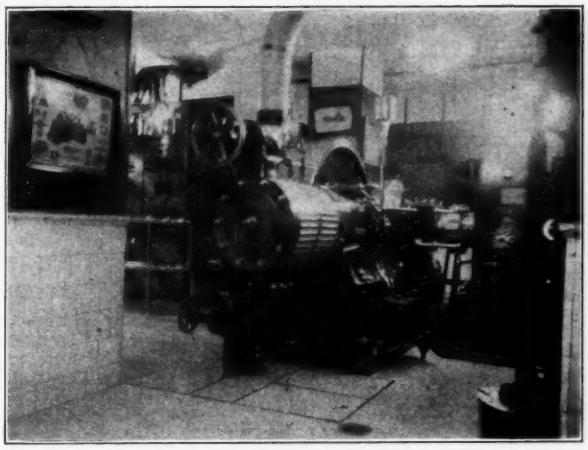


FIG. 4. ENGINE NO. 3 WHICH HAS BEEN IN CONSTANT SERVICE 25 YR.

Figure 3 is a plan of the entire power plant showing the three engine generator sets installed. Engine No. 1 is an 8 by 12-in. Skinner counterflow, direct connected to a 40-kw., 110-v., 354-amp., 280-r.p.m. Westinghouse direct-current generator. The present engine was installed in 1927 but the generator is part of the original installation made in 1904 and although operated practically every day, the commutator has never been turned. The unit is now used as a standby.

Engine No. 2 is a 14 by 15-in., 135-hp., Skinner Universal Unaflow, direct connected to a 60-kw., 110-v., 546-amp., 282-r.p.m. Westinghouse direct-current generator. This old generator is of generous design, however, and has been rerated at 75-kw. The unit is used for about 10-hr. night service on week ends and Sundays.

For service during the day and early evening, about 14 hr., Engine No. 3, shown in Fig. 4, is used. This is a

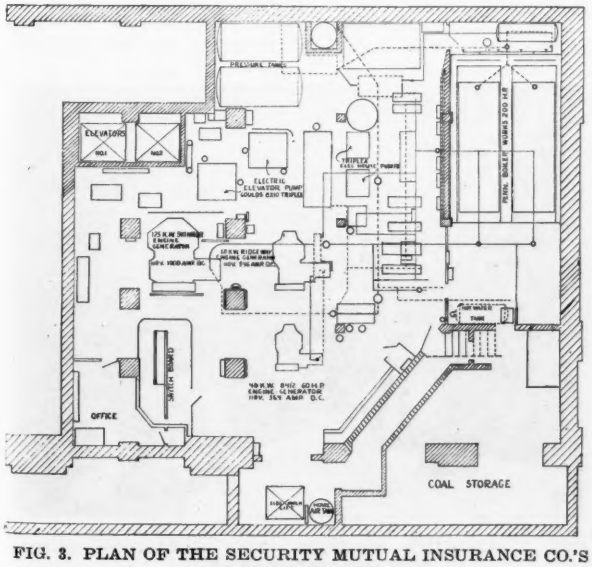


FIG. 3. PLAN OF THE SECURITY MUTUAL INSURANCE CO.'S POWER PLANT

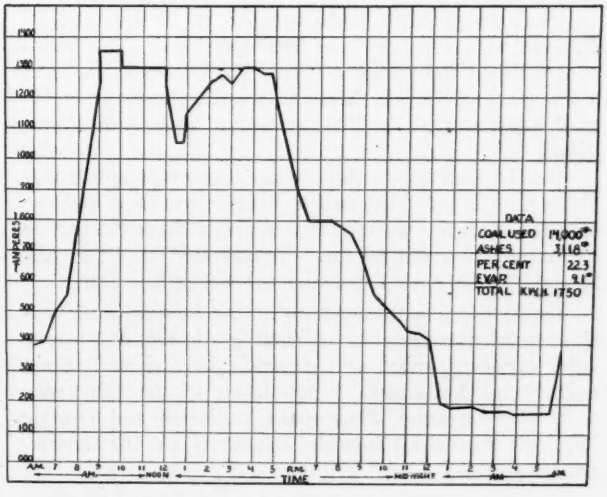


FIG. 5. A TYPICAL WINTER DAY ELECTRIC LOAD

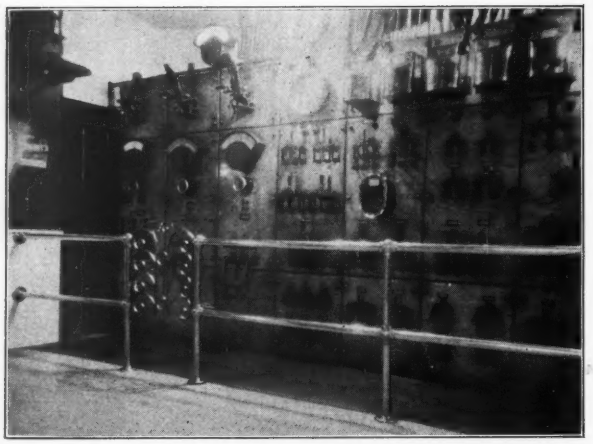


FIG. 6. THE SEVEN-PANEL GRAY SLATE SWITCHBOARD

16 41/64 by 16-in. Skinner counterflow direct connected to a General Electric 125-kw., 125-v., 1000-amp., 250-r.p.m. direct-current generator. The machine is part of the original installation and was rebored only once; that was in 1927 after 22 yr. of service.

Electric distribution is taken care of by a 7-panel gray slate switchboard. Electrical output is totaled by a master meter while the seven feeder circuits are equipped with individual meters. A typical winter day electric load is shown in Fig. 5 and a view of the switchboard in Fig. 6.

Elevator Cables in Service 25 Yr.

Two 3000-lb., 500-ft. per min. Standard plunger elevators serve the building. Water for the operation of these elevators is supplied either by a Worthington 14 and 20 by 10 by 15-in. compound steam pump (stand by use only) or by two 8 by 10-in. Goulds vertical single-acting triplex pumps, Fig. 7, belted to a 40-hp. motor under the control of a Cutler-Hammer elevator control panel and Mason regulators. A Worthington 4 by 8-in., V.T.S.A. elevator booster pump driven by a 10-hp. motor and 5 by 6-in. air compressor driven by a 5-hp. motor complete the elevator equipment. Cables on these elevators have been in service 25 yr. and are still passed by the inspectors as in good condition.

The two pressure tanks are 6½ ft. in dia. and 10 ft. long with a capacity of 2400 gal. each. The pump control is set for a high mark of 170 lb. per sq. in. and a low mark of 160 lb. The two triplex pumps are operated alternately. A 4020-gal. surge tank is also provided.

On the floor above the engine room, a complete machine shop is provided and in winter this shop and the elevator shaft are warmed by air drawn from the engine room by a ventilating fan. In summer, this fan discharges directly outdoors over the top of the boiler.

In addition to taking care of the heating and ventilating of the Security Mutual Building, a 10-story brick building, steam and electric power is sold to six neighboring buildings. A tabulation of the cubic contents above ground, floor space, radiation and electric load of these buildings is tabulated in the accompanying table.

Heating charges are made on a flat rate of 50 cents per square foot per month payable twelve months a year. These charges are calculated on the total radiating surface including the feeder lines outside of the Security Mutual Building. The lines outside of the building are installed and owned by the customers. Electric power is sold at a flat rate of 5 cents per kilowatt-hour. This load, with the exception of a small motor-driven ammonia compressor in the Connelly meat market, bakery motors and restaurant fans, is largely lighting.

Approximately 2000 t. of coal at an average cost of $5.30 per t. is burned each year. The heating load extends over 7 or 8 months, steam for this purpose being supplied largely by the engine exhaust. During the remaining four months when there is no heating load,

DATA ON BUILDINGS SERVED BY THE SECURITY MUTUAL PLANT

Building	Service	Cubic Contents Cu. Ft.	Renting Space-Sq.Ft.	Radiation Sq.Ft.	Monthly Load Av. Kw. Hr.
Security Mutual	Office Bldg.	1,200,000	15,541	73,000	25,948
Carnegie Library	Library	211,500	3,483	10,500	885
Haley	Grocery	104,500	627	8,000	637
Connelly	Meat Market	209,000	1,264	16,000	2,258
Yavis	Club	33,500	660	2,000	424
Red Men	Club	54,500	707	3,500	452
		1,813,000	22,282	113,000	30,604

the engines exhaust to the atmosphere except for feedwater and house hot-water heater. Boiler feed makeup is taken from the city mains and treated.

Plant Makes Over $8000 a Year

Taken over the entire year, the plant shows a gross coal consumption of about 8.5 lb. of coal per kw-hr. while the same ratio over the four summer months runs about 6.8 lb. Of this, about 5.2 lb. is used by the engines for power generation and the remaining 1.6 lb. for steam pumps and plant losses. Current for elevator service averages close to 4700 kw-hr. per month or over the entire year an average of 7.1 kw-hr. per car mile.

In a survey made some time ago by an outside consulting engineer, current was found to cost about $0.0083 per kw-hr., exclusive of labor and boiler room supplies, but taking into account the value of exhaust steam used for heating. With no credit for exhaust steam, this value would be increased to $0.0138 per

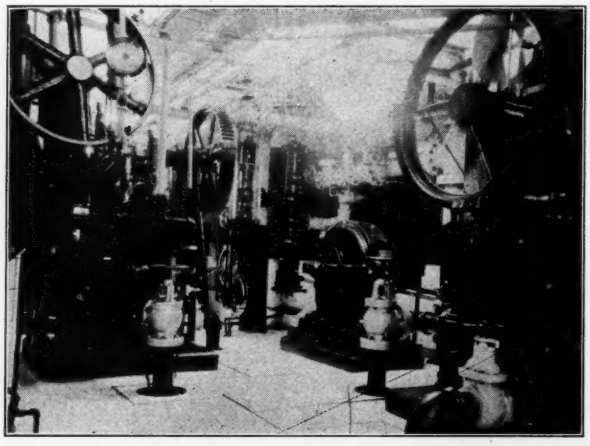


FIG. 7. LOOKING BETWEEN THE ELEVATOR PUMPS TOWARD THE ELEVATORS

No.____ **Monthly Power Plant Expense Sheet** ____ 19__

BOILERS H. P. STEAM AND EXHAUST LINES.

Coal Lbs. @ $ per Ton. Describe
Carting Ashes Loads per Load
Boiler Compound Lbs. per Lb. Kind.
City Water "Plant only."
Hose, Boiler Gaskets Tools.
Repairs Boilers, Arches, Lines.
Water Glasses and Gaskets.
Feed Water Heater and Lines.
Boiler Feed Pumps and Meter.
CO^2 Maintenance.
Extras.

ENGINES AND GENERATORS.

Repairs Engines. Repairs Generators.
Packing used.
Oils and Greases. Switch Board.
Cotton Waste.
Repair Traps, Etc.,
Extras.

Labor Men $

HOUSE PUMPS AND ALL CONNECTING LINES.

Packing Steam. Water.
Valves.
Repairs Pumps.
" Motors.
Tanks, Hot & Cold and Lines
Extras.

ELEVATORS AND ALL CONNECTING APPARATUS.

Motors and Belts. Cars.
Controls and Lines. " Fibres.
Extras. " Cables.
Waste, Oils, Grease, Etc.,
Triplex Pumps. Plunger Packings,
" " Packings. Leather Valves,
" " Valves, Tank Compound,
" " Extras, Extras,

Compound Pump.
" " Packings, Air Compressor and Lines,
" " Valves.
" " Extras.

Work Total, Hours per Hour, $

GENERAL ACCOUNTS.

Soaps Hand, Soap Common, Tile Cleaner,
Laundry, Lamps Plant,
Mops. Polishes
Paints and Brushes, Stationery
General Supplies.
Tools.
Motors and Fans Plant,
Extras.

DAY ENGINE AND PUMP REPORT

_____, 19__

	Engine 1	Engine 2	Comp. P.	Elect. 1	Elect. 2	Jack	S. House	Elect. "1	" "2	Vac. 1	" 2	B. F. 1.	" 2	Sump. 1	" 2	Air C.	Trips 1.	" 2.
6:30 A. M.																		
7:00 "																		
6:00 "																		
11: '27																		

REMARKS:

Condition of Apparatus and Wants:

DAILY COAL TICKET

_____ 19__

SHIFT No. 1.				SHIFT No. 2.				SHIFT No. 3.			
Lbs. Coal	Ash	%Ash	CO_2	Lbs. Coal	Ash	%Ash	CO_2	Lbs. Coal	Ash	%Ash	CO_2

Kind	Kind	Kind
Fireman	Fireman	Fireman

Total Coal Used ..... Lbs.
" Ashes Made ..... "
" % Ashes ..... "
Lbs. Water to One of Coal ..... "
Cost of Evaporation, per 1000 lbs ..... Cts.
CO_2 as Made for 24 Hrs. ..... %
Steam Line, Shift 1 ..... 2 ..... 3 .....
Water Level, ins., Shift 1 ..... 2 ..... 3 .....

CREDITS.

Outside Work ..... Hours ..... per Hour - - - - - $ .....
Elevator " ..... " ..... " - - - - - - - .....
Elevator daily care of monthly Chg. - - - - - - - - .....
Elevator extras all - - - - - - - - - - - - .....
Heating Credits, Block, Hot Water, Library, Connelly, Haley, Etc., - - .....
All other Charges Foreign to the Plant - - - - - - - .....
$ .....

Current generated ..... K. W. H. for Month cost net ..... cts.

Current @ ..... Selling Price $ ..... Total Expenses $ ..... { Profit $ ..... / Loss $ .....

Elevators made ..... Trips and Cost per Trip ..... cts. for current.

Explanations:

NOTE.—All House Pumps and Lines are a Block charge. Daily care of Elevators, cleaning, oiling, etc., not a Plant charge. Foreign charges as above are Credits to Plant.

FIREMAN'S REPORT

	SHIFT 1	SHIFT 2	SHIFT 3
Quality			
Clinkers	"	"	"
Builds up	"	"	"
Shook or Cut	"	"	"
Rake or Poke, times	"	"	"
Steam Drop, Why	"	"	"
Draft	"	"	"
Load	"	"	"
Live steam used, hrs.	"	"	"

CONDITION OF APPARATUS AND WANTS

1 2 3

FIG. 8. SOME OF THE RECORD FORMS USED IN MAKING THIS PLANT A SUCCESS

kw-hr. Steam cost including operating charges and fuel was about $0.35 per thousand pounds.

This engineer estimated that the plant saved $4957 a year over purchased power for their own building made a profit of $2235 on the sale of power and another profit of $1011 on the sale of steam, a total annual profit of $8203 a year.

Labor charges in the engine room were not included in the comparison because this item would be the same for either generated or purchased power, as the power plant is now operated by one man who would still be required most of the year for firing the heating boiler even though power were purchased. Another man is on duty but his time is taken up with building and elevator maintenance and outside work which would also be necessary with purchased power.

Fixed charges are not considered as the plant is now 25 yr. old and has already been charged off the books. Investigation of past cost records showed an average of about $13 a month for engine supplies and $8 a month for engine and generator repairs.

This rather extraordinary record of industrial power plant operation was the result of continued effort on the part of the operating force. Complete records, some of which are shown in Fig. 8, have been kept. The success of this plant has been due largely to Chief Engineer Hyde's ability to see the cumulative advantage of small gains and coöperation of his men. He says, "We are, and always have been, watching to see whether we could lessen the operating costs and decrease waste. This watchfulness is responsible for the low-operating costs we show. It is nothing that anyone cannot do but it is something that many do not do. If they did, many of the small plant operators would be encouraged rather than discouraged. If we can and have made a success under adverse conditions, why cannot others?"

Government Policies Affecting Public Utilities

From an Address Before the Natural Resources Branch of the U. S. Chamber of Commerce by General Charles Keller, Byllesby Eng. & Mgt. Corp.

PUBLIC OWNERSHIP and operation of any part of a complicated, constantly changing and expanding industry, such as the electric industry, has been shown to be undesirable by practically every experience with which the speaker is acquainted, and he believes, therefore, that the entrance of government into the hydroelectric field would confer no real benefit on the people while, at the same time, it would jeopardize and probably destroy the investments made by the many thousands of citizens in public utility securities.

The Federal Water Power Act has been in existence for practically 9 yr. During that time, except as it has, in three or four well-known instances, been, by Congressional interference, prevented from operating, it has served the purpose for which it was designed, namely, the opening of opportunity for the development, under workable conditions, of water power sites on the public domain, on Indian lands, within or affecting the national forests, or on navigable waters of the United States.

The Act provides that such development shall be performed under license whose period may not exceed 50 yr. At the close of this period, the United States may take over the property of the licensee upon payment to him of its fair value and, in addition, any damage suffered by him as the result of the separation of this property from the system of which it forms a part. Moreover, the Act also reserves to the United States, and to any State or municipality, the right *at any time* to take over by condemnation the property of any licensee. To the extent that these provisions serve to assure the citizen that values belonging to the people are being merely licensed or leased and that no one is to be permitted to profit extravagantly from exploiting these resources, they may serve a useful purpose, but since they visualize ownership and operation by the United States they are not to be considered as enunciating a sound policy. Indeed, they seem to have been based on the erroneous idea, still prevalent, that water power—any kind of water power—is more valuable than power generated by other means and that the privilege of developing it is, therefore, unusually valuable.

My main purpose is to draw attention to Sections 19 and 20 of the Act and to the effect a recent order of the Federal Power Commission, based on the provisions of these Sections, if enforced, would have.

Section 19 confers on the Commission regulatory authority as to rates, service and security issues of a licensee operating in a State having no agency for regulating all these matters. Section 20 confers similar authority in the case of a licensee engaged in interstate or foreign business.

I have no knowledge of the history of these two Sections of the Act or of any discussions of them in Congress during the debates on the bill but it seems certain that, had Congress had a correct picture of the industry, neither Section would have been enacted in its present form.

Practically until this year, the Conowingo case being the only known exception, the Commission has paid no attention to Sections 19 and 20. On February 28, 1929, however, the Commission issued its Order No. 28, under which it proposes to exercise the power conferred in Section 19 and 20 to regulate the issue of securities. These orders seem to contemplate no restriction of this regulatory power to the licensed project itself.

The benefit of regulating security issues when rates, services, and consequently, earnings or returns are regulated is, in my mind, practically nothing and, if rates and services are not regulated, then certainly the regulation of securities is idle labor.

I, however, gladly concede the value and the importance of regulating rates and service when such regulation is intelligently and impartially done, with recognition of the basic rights involved. It seems to me, therefore, that the Commission has chosen to discharge the least important of the duties imposed upon it in Sections 19 and 20 and, at the same time, its order appears to be at variance with what must have been

the intent of Congress, namely, to limit regulation to the licensed project itself.

As an illustration of what may happen under these Orders No. 28, I cite a case with which I am familiar. The Northern States Power Co. of Wisconsin, a wholly owned subsidiary of the Northern States Power Co. of Delaware, owns and operates all public utility properties of the Northern States system in Wisconsin, its territory lying west of the approximately north and south line through LaCrosse, Angelo, Neillsville and Chippewa Falls. This Wisconsin system is supplied with energy by steam and water power plants not under the jurisdiction of the Commission. Most of these plants are in Wisconsin and the remaining supply comes from interconnected properties in Minnesota which are, equally, independent of the Commission.

The entire Northern States system has assets of over $239,000,000, and the Wisconsin portion of the system has property whose value may be in the neighborhood of $40,000,000. Among this property is the Chippewa reservoir for which the company holds a license from the Commission. This reservoir cost less than $1,500,000 to construct. It has no power plant, the stored water being used in non-licensed plants below it, but, because of its position as an element in the Northern States system, some of the energy made possible by the storage may be transmitted to Minnesota and, accordingly, the reservoir is affected by Orders No. 28. If, therefore, the Northern States Power Co. of Wisconsin should desire to issue a refunding mortgage covering all of its property, under Orders No. 28 the company would have to submit the entire transaction not only to the R. R. Commission of Wisconsin where it belongs, but also to the Federal Power Commission. In other words, an investment of $1,500,000 may be used as a means to affect seriously the interest of a property valued at $40,000,000. And this, too, in a state in which the local Commission is amply qualified, and is known to be anxious to give the public whatever protection can be had by regulating securities.

I might cite other similar cases, but one seems enough to illustrate my point that the provisions of Section 19 and 20 are too broad, that Congress had an altogether different set of circumstances in mind, and that Orders No. 28 are, at present at any rate, needless. If there be cases in which benefit will arise from regulating securities, and I can conceive of few, if any, each of these should be covered by a carefully drawn special requirement in the license of these projects. Indeed even this measure is unnecessary since the Federal Power Commission may at any time take jurisdiction under Sections 19 and 20 merely by giving appropriate instructions to the holders of licenses for the projects to which it may desire to apply the provisions of these sections.

I understand that Orders No. 28 are now being reconsidered. It is to be hoped that careful investigation of the effect of these orders will now be made and that due weight will be given to the views regarding them expressed in the letter from the President of the U. S. Chamber of Commerce to the Chairman of the Commission dated April 25, 1929.

LUBRICANTS for worm gears should have approximately the same consistency as a medium steam cylinder oil with a viscosity of about 120 to 150 seconds saybolt at 210 deg. F.

Semi-Annual A.S.M.E. Meeting Salt Lake City, July 1-4

FOR THE SEMI-ANNUAL meeting of the American Society of Mechanical Engineers, to be held at Salt Lake City, Utah, from July 1 to 4 inclusive, a diversified program of technical papers and entertainment features has been arranged. Headquarters for the meeting will be at the Hotel Utah in Salt Lake City and full details can be obtained from the secretary of the A. S. M. E., 29 West 39th St., New York City or from the management committee of the A. S. M. E. at Salt Lake City, of which W. H. Trask, Jr., is chairman.

In connection with this meeting, the Six National Parks Tour will be held beginning June 17. Members of the society are to spend a month visiting Glacier, Yellowstone, Zion, Grand Canyon, Bryce Canyon and Rocky Mountain National parks, stopping for the Salt Lake City meeting. Details of this trip may also be obtained from the A. S. M. E. secretary.

Program for the meeting is as follows:

MONDAY, JULY 1

9:30 a. m. Business meeting.
10:00 a. m. Council meeting.
Technical Session.
Recent developments in Air Transport, P. G. Johnson.
The Development of Steam Turbine Oils, A. J. Turner.
12:15 p. m. Joint luncheon with Chamber of Commerce.
2:30 p. m. Technical Session.
Modern Practice in the Installation and Starting of Hydroelectric Units, Chas. V. Foulds.
Steam Distribution in Beet Sugar Factory, Fred W. McEntire.
4:30 p. m. Leave for Saltair Beach.
5:30 p. m. Bathing at Saltair.
6:30 p. m. Dinner on Pavilion at Saltair.
8:30 p. m. Dancing on Pavilion at Saltair.
10:00 p. m. Return to Salt Lake City.

TUESDAY, JULY 2

9:30 a. m. Conference of Local Sections Delegates.
Technical Session.
Operations of the Utah Copper Company, H. G. Goodrich.
11:00 a. m. Leave Salt Lake City for Bingham.
Inspection of Utah Copper Mine and Mills and Garfield Smelter.
5:30 p. m. Arrive Salt Lake City.
7:00 p. m. Banquet at Hotel Utah.

WEDNESDAY, JULY 3

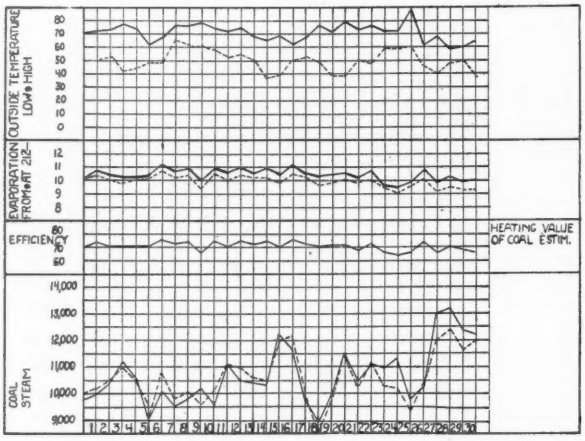
9:30 a. m. Technical Session.
Recent Developments in Mechanical Loading, O. G. Sharrer.
The Fuel and Smoke Problem in Salt Lake City, Geo. A. Orrok and W. H. Trask, Jr.
12:00 m. Tabernacle Organ Recital.
1:00 p. m. Visit Temple Square.
1:30 p. m. Luncheon at Newhouse Hotel.
2:15 p. m. Sight-seeing tour of Salt Lake City.
4:00 p. m. Reception to Visiting Ladies at home of Mrs. Geo. H. Dern.
7:00 p. m. Dinner on Hotel Utah Roof Garden.

THURSDAY, JULY 4

10:00 a. m. Leave for Ogden Canyon.
1:00 p. m. Luncheon at Hermitage Inn.
2:30 p. m. Visit Ogden City Wells.
5:00 p. m. Arrive Salt Lake City.
6:00 p. m. Dinner at Hotel Utah.
9:00 p. m. Leave for Yellowstone Park.

Graphic Performance Charts Increase Economy

ABOUT 6 YR. AGO, I secured employment in a plant which was used for heating and locomotive service. The plant was nearly new and had up-to-date equipment.



COMBINED OPERATING CHART SIMILAR TO THOSE USED FOR GRAPHIC REPRESENTATION OF INDIVIDUAL PERFORMANCE WHICH LED TO MORE ECONOMICAL OPERATION

The boilers were fitted with steam and air-flow meters which, however, were out of order. The boilers were hand-fired and had natural draft. Coal consumption and boiler output were both estimated, which is far from a satisfactory procedure.

About this time, a drive for fuel economy was started as our efficiency was very low, so I put the meters in working condition and then calibrated them. Next, platform scales were secured and the coal weighed as fired. A little improvement in economy was noted but conditions were still far from satisfactory.

Arousing the interest of the firemen was the next move in our betterment program. This was accomplished by plotting the daily performance of each fireman in graphic form. I made two of these charts; one concerned the individual shift while, in the second, the three shifts were combined as shown in the illustration. This form of presenting the relative daily performances of the firemen aroused a keen competition between them and resulted in raising the efficiency about 15 per cent. Since then, this higher efficiency has been closely maintained.

Mechanicville, N. Y. R. F. LEACH.

That Water Level—Where Should It Be?

IT WAS WATCH changing time and for a moment or two the day and afternoon crews were "ganged up." The "young one" had been up for his "ticket" the day before and the following dialogue took place:

"How did you make out with the examiners yesterday, Claude?"

"Not too bad, Berte, although I still am puzzled over one question. They asked me where the water level should be in a boiler. Now, I took it to mean the operating level and answered that in common practice it was kept at between one and two gages. I got the impression, however, that it didn't satisfy them; in fact, one of the examiners pressed me to state definitely what I meant by 'two gages.'"

"Well," said Berte the day man, "two gages would be lots of water in some cases. When I was with the copper company, 3 in. was all that we carried and that was less than one gage. That, however, was an exceptional plant, half the boilers being waste heat fired, were block loaded. That left the load swings, which were fairly heavy, to be taken care of by the oil-fired boilers. It had been found that a higher level of water in the boiler would be liable to result in pulling over some of it with the steam. Two gages certainly would not do there."

"On the other hand," Fred, the afternoon man spoke up, "that paper factory I was with called for the opposite condition. The water was carried as high as possible—all of three gages and a half. When they opened up the lines on that paper machine they took *some steam;* at a higher rate, in fact, than the boilers could furnish it. So the answer was to make an accumulator of the boilers. Wet steam didn't bother. The salvation for the water tender was to carry the water high. Two gages would not have done; the water would have been pulled out of sight; seems to me that plant conditions dictate the water level."

"Now, what is all this argument about," asked the chief, good-naturedly, as he came in. After listening to what it was all about, he was appealed to for his opinion.

"Well, whether it be high or low, is not as important a matter as keeping the level constant," he said, as he went away.

"Now, I wonder if that is the answer that examiner wanted," mused Claude as he started on his round.

Montebello, Calif. GUILLERMO PABLO.

Commutator Maintenance

COMMUTATOR TROUBLES on direct current generators and motors are varied and numerous, commutator trouble being experienced to a greater or lesser degree on all installations. A great deal of trouble is often caused through wear at the commutator; there is a natural tendency for this to wear eccentric and when a commutator becomes eccentric, it causes serious chattering at the brushes and throws the commutator out of balance.

Geometrically no commutator is absolutely round but nearly enough so for all practical purposes; however, there is always a tendency to wear out of round, which is aggravated by hard, abrasive brushes and excessive play in the bearings. A commutator in this condition causes the brushes to chatter and leave the commutator surface momentarily; this causes more or less serious sparking. The continual vibration of the brushes may bring on other defects such as the loosening of contacts, etc., the effects being worse as the speed increases. The condition can be detected by measuring round the commutator circumference with a pair of calipers, and if found to be greatly out of round, it should be turned up.

Turning a commutator in its own bearings is likely to duplicate this fault, so, after turning, a commutator should be calipered to detect any "out-of-round"; finishing by grinding is a good way of removing it, owing to the lighter cuts taken.

Vibration of the armature may also lead to sparking; this may be caused by the armature being mechanically or electrically unbalanced, too much play in the bearings, clumsy joints in the connecting belt or loose foundation bolts. Vibration due to unbalance is not common; machines are thoroughly tested for this before they leave the factory. Mechanical unbalance may be introduced through wear at the commutator as already mentioned, or by electrical unbalance through electrical faults in the armature windings. Too much play in the bearings is always possible, which shows the necessity for adjustment or rebushing when the bearing has worn appreciably. This is shown by the difference in the air gaps at the top and bottom of the armature; normally these should be approximately equal but when there has been appreciable wear, the gap between the armature core and the top pole pieces greatly exceeds the gap between the armature and the pole pieces at the bottom. This air gap should be checked every three months.

A thick feeler gage can be pushed into the air gap until the correct thickness is found, and if there is any great difference, the bearing should be readjusted. Clumsy joints in a belt will cause sparking; each time the joint passes round the pulley, the armature receives a jolt. A flat may develop on the commutator at the point where the joint passes round the pulley. Loose foundation bolts will also lead to vibration and the tightness of these should be periodically tested with a spanner. Where a motor is coupled direct to its load or connected through gearing, vibration may be transmitted from the armature shaft, either from the load or from the gears; a wise precaution, in these cases, is to couple the motor to its load through a flexible coupling.

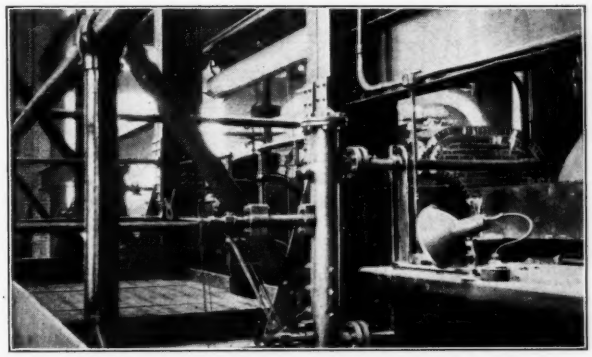
Brentford, England. W. E. WARNER.

Special Light for Water Column

IMPORTANCE OF KNOWING the level of water in a boiler is emphasized by the fact that the answer to the question, "What is the first duty of a fireman on entering a boiler room?" which is so frequently put by examiners for engineers' licenses, is look at the gage glass or determine the level of water in the boiler.

Notwithstanding the importance of knowing this level, many gage glasses are so poorly placed or so inadequately lighted that it is difficult to see the level in the glass from the firing floor and mistakes are often likely to occur because of this difficulty.

Gage glasses that reduce this difficulty are in the market but many boilers are not equipped with such improved devices. A simple and unique method of providing ample light for a gage glass, with apparatus



LIGHT THROWN DIRECTLY ON GAGE GLASS FROM ELECTRIC LAMP ON TOP OF BOILER MAKES POSSIBLE EASY DETERMINATION OF WATER LEVEL FROM FIRING FLOOR

which is usually available in any boiler room as shown in illustration, was found in the Hamilton, Ohio, municipal power and light plant. It consists simply of an ordinary electric light placed in an appropriate position on the top of the boiler to so throw its rays against the glass that the level will be easily discernible from the floor. FIELD EDITOR.

Cup Washers Formed Without Special Mold

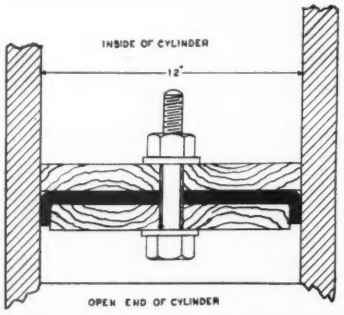
DURING THE PAST year, methods described by readers for forming cup washers for use in the power plant, stress without exception, the necessity of a special mold of wood or iron to form the cup. Such molds are more or less difficult to make and an iron one of large size is expensive.

First class cup washers can be molded by anyone with nothing more costly than two disks of wood, a bolt, a nut and two iron washers. Suppose you desire to form a 12-in. diameter cup washer as shown in illustration, from first class leather stock, you would first cut a piece of leather 14¼ in. in diameter, if the cup is to be one inch deep. Then you would cut a disk of wood, A, 12 in. dia. and of any thickness sufficiently strong and another disk of wood, B, 1 in. thick and 11¾ in. in dia.

Soak the leather for a minute or two in warm water, not steaming hot, then place it between the two disks of wood as shown, tighten up the nut and force the

whole outfit into the open end of the cylinder in which the leather is to be used. If possible, the cup should be left in the cylinder for a few hours and then taken out and the bolt removed.

With this simple method, the leather will be formed quite as well as in an expensive mold and it will serve quite as well as any that may be bought. Only the very best leather stock procurable should be used for this purpose. If the leather is hard and dry, it should be soaked longer in the warm water than if it is soft and pliable. If the leather stock is extra thick, make B correspondingly less in diameter than A.



TWO WOODEN DISKS AND A BOLT AND NUT ARE THE ONLY SPECIAL PARTS REQUIRED TO FORM A CUP WASHER

Smaller cup washers can be molded by using a short piece of iron pipe whose end has been well reamed. The end of the pipe may be slightly tapered by using a round or half round file to remove any burr left in cutting it.

Uffington, Ont., Can. JAMES E. NOBLE.

Fitting Keys

IN REFERENCE to Mr. Warner's article which appears on page 591 of the May 15 issue, I would like to offer something further relative to fitting keys. Quoting from the latter part of the article, "keys should be carefully fitted so that they bear their entire length in the keyway. No packing should be used between the key and keyway but if the key is not a tight fit, a new one should be fitted." In the main, I agree with this. There is, however, something more that should be said about the matter in order to have a better understanding of the purpose of keys and how they should be fitted.

It seems to me, from my machine shop training and practice, that the purpose of a key is not to tighten a wheel or any other mechanism on a shaft but rather to prevent it from turning on the shaft from the position it was designed to occupy. The wheel, arm, lever, as the case may be, should be of such a fit on the shaft, as not to require the assistance of a key, especially so where a driving or forced fit obtains. If a key, fitting tightly at the top and bottom, were driven tightly home, the tendency would be to ease the bore of the wheel from the shaft and thus partly destroy the benefit of the tight fit, unless the hub were very large and could resist the wedging force of the driven key.

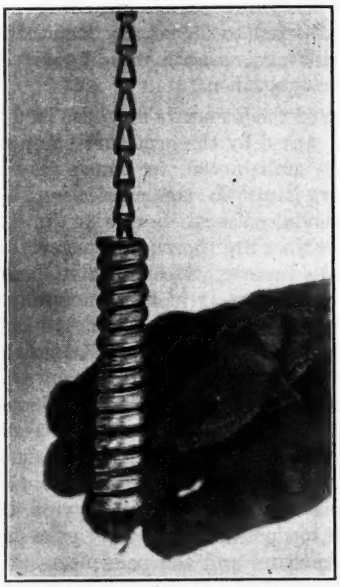
Where proper fits prevail between wheels and shafts, the keys should be fitted tightly sideways and just fill the space at the top and bottom without exerting undue pressure in those directions. This will secure the wheel from turning circumferentially on the shaft, without detracting from the holding power between shaft and hub.

If a wheel or arm is not a good tight fit on the shaft, then a top and bottom fitted key must be resorted to for the double purpose of securing the wheel on the shaft and preventing it from turning and it should just "fill the hole" sideways without being the least bit loose and should fit top and bottom tightly for the whole length of the key. In order to secure such a fit, the point of the key should be a little tighter than the part near the head, because in driving the key home finally, the repeated blows of the hammer will tend to swell the head end of the key. In this way, a perfect fit can be obtained and the key will never back out of itself. Of course it is assumed that the parts are properly proportioned in relation to one another and that the workmanship is not positively bad.

Brooklyn, N. Y. CHARLES J. MASON.

Chain Handle Made of Flexible Tubing

TO MAKE a small handle for a chain attached to a damper, a piece of old flexible tubing was placed around the chain, the end of which was held down an inch or



FLEXIBLE TUBING WRAPPED AROUND A CHAIN PROVIDES CONVENIENT MEANS FOR HANDLING IT

so in the tubing and the interior of the tubing was run full of lead. This handle had a good grip and was heavy enough to keep the chain from swinging and dangling.

Missouri Valley, Iowa. FRANK W. BENTLEY, JR.

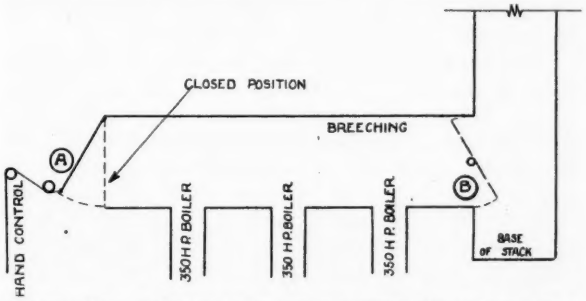
PRODUCTION OF ELECTRIC POWER by public utility power plants in the United States for March, 1929, as reported by the Geological Survey, Department of the Interior, reached a total of 7,989,212,000 kw-hr., an increase of 10 per cent over that of March, 1928. Of this amount, 4,850,922,000 kw-hr. were produced by fuels and the remainder by water power.

Questions and Answers

Damper Location Should Be Between Boilers and Stack

WE HAVE A damper located in the breeching as shown at A in sketch and propose changing its position to B. Please let me know which position is the better. The present damper opens to the atmosphere in the boiler room; the proposed damper would be at the entrance of the stack. If the damper position is changed, the opening at its present position would be closed.

A. E. L.



AMONG THE ADVANTAGES OF DAMPER LOCATION AT B IS THAT OF MORE EVEN TEMPERATURE OF STACK GASES

A. It is almost universal practice to have the damper located in the position you propose it to have, that is, in the breeching just before it is attached to the stack. The principal reason for this location is that you can secure better regulation of the draft at the boilers than you can with the damper located in the open end of the breeching. For example, your stack temperature will remain practically constant with the damper located as proposed. Thus, at any time greater draft is needed, opening the damper instantly reduces the resistance through the damper opening and gives the desired draft in the boiler furnaces.

With the other arrangement, the stack temperature does not remain constant due to the inlet of cold air passing through the damper when it is partly or completely opened; the farther open the damper, the colder the stack. Consequently, if draft is required at the boilers, the closing of the damper merely prevents the inlet of cold air and the stack must be heated up by gases from the boiler before you secure the full capacity of the stack. This may take some time, as your stack may be almost as cold as when starting a new fire. The same lag in reducing draft takes place when the damper, as you have it now located, is opened, for it takes some time to cool the stack down.

Another fault of the damper arrangement which you now have is that you cannot definitely control the draft in the boilers as the damper position must change with the stack temperature in order to give the same draft on the boilers. Thus, if you wish to cut down the load on the boilers, you open up your damper an amount which gives you the draft you desire in your boiler furnaces. As soon, however, as the cold air starts to rush into the breeching and up the stack, the stack draft decreases which naturally decreases the draft in your boiler furnaces necessitating a partial closing of the damper. With the damper located as you propose, the stack draft is changed only by the friction of the stack gases, which is comparatively small, so that, for any particular position of the damper, you can practically depend on the draft in the furnaces being constant.

Generator Counter Torque

WHAT IS meant by the counter torque of a dynamo?

A. In order to understand what is meant by counter-torque of a generator, it is necessary to consider the action of the machine as a whole. The generator as is well known, depends for its action upon the fact that when a conductor is moved across a magnetic field, a current is induced in the conductor. It is known, however, that when a conductor carrying a current is placed in a magnetic field, there will be a magnetic force acting upon the conductor tending to move it out of the field. In other words, there is a motor action. This magnetic force is always in a direction opposite to the mechanical force which drives the conductor across the field and which causes the current to flow in the conductor. This, then shows how a generator is loaded. The source of driving power turns this armature in a given direction which produces a voltage and causes a current to flow; the current through the armature conductor in turn produces a reverse, or counter-turning effort to that produced by the prime mover. This counter-turning effort is known as the counter-torque of the generator and neglecting friction and electrical losses constitutes the load on the generator.

Staybolt Application

1. WHAT IS the projected area of the unbalanced spaces in a water leg having staybolts and one without them?

2. Do staybolts support the outer sheet any and if so, how much?

N. A. B.

A. 1. The projected area is considered as of the outside because the area is greater here because of the radial position of the staybolts. Since the outer area is the greater, it is also the weaker.

2. The staybolts are designed to support the outer sheet completely.

Editorial Comment

Possibilities of the 1000-Deg. Turbine

Speculation will doubtless run riot as to the possibilities of the plan for operating a 10,000-kw. turbine with throttle steam taken at 400 lb. and 1000 deg. F. from a separately-fired superheater, at the new Delray Power House No. 3, as discussed elsewhere in this issue by J. W. Parker, chief engineer of The Detroit Edison Co. As Mr. Parker states that the installation is frankly experimental, naturally initial difficulties are to be expected in both turbine and superheater, since pioneering developments in the power field seldom commence without a few "bugs." But with everyone recognizing that it is an experiment, trouble will be met as it arises and success will reflect even greater credit on the pioneers.

As Mr. Parker points out, the primary object of supplying steam to the turbine at 1000 deg. and at what is now considered moderate pressure—350 to 400 lb.—is to eliminate the necessity of reheating the steam after it has passed part way through the machine, since moisture content of more than 10 per cent in the steam in the lower pressure stages of the turbine is believed to cause serious erosion and high leaving losses.

By raising the steam pressure to 1200 lb. or higher, the same objective has, of course, been sought. While no unsurmountable difficulties have been met with either the turbines or boilers at this pressure, in the central stations already using medium pressures, the high-pressure cycle is superimposed on the former low-pressure cycle, an arrangement that still leaves something to be desired because of the complications involved with the necessary reheat piping and equipment.

Moreover, in the industrial plant, unless some use can be found for steam at pressures of 200 or 300 lb., for process work, the 1200-lb. initial pressure may not afford the same advantages as it does in the central station, owing to the impracticability, from a mechanical and thermal standpoint, of designing a turbine for too wide a range of expansion. Possibilities of the reciprocating engine for the high-pressure cycle will be demonstrated in this country in the near future.

For the industrial plant, the desirability of raising pressures depends so much on the balancing of initial and exhaust steam pressure and quantity against electric load in each individual case that generalizations are unwise. Thus it may be that the raising of total steam temperature in the industrial plant may afford a method of balancing heat in process steam against electric load that will enable the process steam to be supplied at the lower pressures without generating it at the higher boiler pressures.

The effect of extracting steam for heating feedwater or for process work from a turbine taking throttle steam at 1000 deg. and expanding the remainder to about 2 in. vacuum, would also be a subject for considerable investigation.

Plotting of the conditions on the total-heat-entropy diagram shows clearly where the gain lies, mostly above the saturated steam line. At 350 lb. pressure and 700 deg. total temperature, each pound of steam, in expanding to a vacuum of 2 in., will make available to the turbine 364 B.t.u. On the other hand, at the same initial pressure and vacuum, but with initial temperature of 1000 deg., the same pound of steam can make available to the turbine 480 B.t.u., a gain of about 30 per cent. Using a cycle with initial steam at 1200 lb., 750 deg., expanding to 2-in. vacuum, with reheat at about 400 lb., the heat made available to the turbine by a pound of steam is about 450 B.t.u., a gain of about 23 per cent over the 350-lb., 700 deg., cycle.

While the difference in heat available to the turbine between the 350-lb., 1000-deg. cycle and the 1200-lb. reheat cycle is only about 30 B.t.u. per lb., the heat-entropy curves show that the final moisture in the first case is only about 5.5 per cent while that in the second case is close to the 10 per cent limit. Furthermore, with the 1000 deg. steam, most of the expansion takes place above the saturation line, the most desirable condition, and this condition is obtained without reheating.

It has occurred to us that, if the Detroit experiment is successful, opportunity is afforded to utilize its economy in connection with the mercury vapor cycle. The steam *pressure* possible with this cycle is, of course, limited by the condensing temperature of the mercury but that limitation does not apply to the steam *temperature.*

Thermal efficiency of the mercury vapor cycle, assuming pure adiabatic expansion, figures out theoretically at about 52 per cent, whether we use a total steam temperature of 700 deg. or 1000 deg., owing to the difference in exhaust conditions. Considering actual expansion, however, for steam at 700 deg. we have an efficiency of 41.5 per cent while for steam at 1000 deg., we obtain an efficiency of 44 per cent, an appreciable increase. In either case, these efficiencies are higher than that of the 1200-lb., 750-deg. cycle with reheat, which is in practice about 33 per cent, neglecting the effect of regenerative feedwater heating, which raises it somewhat.

Performance of metals at high temperatures and pressures is of extreme importance in this connection, owing to the reduction in strength, especially at high temperatures, caused by "creep." It has been the general conclusion of those who have really investigated the subject, such as Mellanby and Kerr, that the safe upper limit of temperature for metals such as nickel-chrome alloys is about 900 deg.

Yet European installations are operating at 25 or 30 deg. above this and the British manufacturer of the turbine for Detroit seems to feel no hesitation in designing for 1000 deg. Valves and fittings are now on the market designed for this temperature. What may occur in the tubes of the separately-fired superheater will be

satisfactorily determined by the test installation at Trenton Channel well in advance of the installation of the turbine at Delray.

On more than one occasion, it has been pointed out that it is never safe to prophesy that because a tendency exists at present it will continue indefinitely in the same direction at the same rate. It is much safer to expect, as previous experience has so often demonstrated, that an entirely new discovery or development will change the entire course of progress. For a number of years, now, power plant progress has been dependent on the effects of steadily increasing steam pressures, with a much slower tendency to raise the temperature, the upper practicable limit of which has been considered to be about 750 deg. It may be that the pioneer work in getting steam temperatures up to 1000 deg., at moderate pressures, may prove to be an unpredictable factor that will change the curve of development. It is too early, of course, for any such prophecy to be warranted. But if it is fulfilled, we shall not be at all surprised. There are more things in heaven and earth, Horatio, than were ever dreamed of in *our* philosophy.

Is Steam Generated Electric Power on the Wane?

Comment on a recent report from A. H. Horton, Chief of the Division of Power Resources of the United States Geological Survey, seems inclined to the belief that the increased output of the water power plants of the country during the last few years definitely indicates that steam generation is on the wane. Also, opinion has been expressed that it would be difficult to predict when steam-generated power will begin to gain on hydroelectric output.

Facts of the case, based on compilations from the Statistical Research Department of the National Electric Light Association, give a picture that is hardly in accord with these views. Attention is called to increasing efficiency in the production of electricity by steam. Amount of coal required to produce a kilowatt-hour of energy has steadily declined in the last few years until now the average for the entire country is 1.76 lb. of coal per kilowatt-hour. The average for greater New York is better, approximately 1.45 lb. The cost of fuel per kilowatt-hour in greater New York has declined from 0.92 cents in 1920 to 0.36 cents in 1928.

Taking for example, the territory included in greater New York, the energy generated by the power companies has increased from 1,724,000,000 kw-hr. in 1920 to 4,384,000,000 kw-hr. in 1928. During that interval the amount of coal used by these plants only increased from 2,052,000 t. to 3,182,000 t. The significance of these figures is more apparent when it is appreciated that this has been possible only because in 1920 it was necessary to burn 2.38 lb. of coal for a kilowatt-hour of electrical energy, whereas in 1928 only 1.45 lb. of coal were required to generate the same amount. These facts indicate conclusively the increasing efficiency of the steam generating plants.

That is one side of the situation. Another is that construction on the majority of the hydro plants that have recently been put into operation was begun or contemplated when the cost of coal was much higher and the efficiency of the steam plants was considerably lower than it is today. Sites were purchased for these projects, contracts were let and material purchased. The cost involved was such that the operators could not help but complete the dams and the hydroelectric power houses. That this work is not continuing in the same proportion as formerly is shown in the reports of the Federal Power Commission, indicating clearly that water power development has been slowing up for the past year.

Water power has an important position among the agencies that motivate the prime movers of the country. Also, there are some hydro plants that are so propitiously located that their contributions are exceptional, as, for instance, Niagara Falls and the new Conowingo plant. But water power, considering the entire nation, must compete economically with steam generation and, from some of these latter observations, it would seem to the Statistical Research Department that additions to the electric power resources of the United States in future will be mainly by steam generating plants.

Gas Lines as a Power Market

Broadening of the super gas service system by means of high-pressure, long-distance gas mains, interconnection of systems and centralized production plants is analogous in principle to the centralized-production, long-distance transmission and interconnection of electric systems.

In fact it has been proved that gas can be economically piped as far or farther than electricity can be economically transmitted. Natural gas is being piped up to 500 mi. from the point of production.

Examples of this tendency are: the super gas service system being developed in Chicago where distribution mains of The Peoples Gas Light and Coke Co. are interconnected with the gas supply systems of surrounding suburban and industrial areas; the system of the Western United Gas and Electric Co. in northeastern Illinois supplying small communities from a central plant; a similar system in northwestern Indiana adjacent to Chicago; another in Connecticut, with one terminal in Hartford and the other in New Haven.

All this development means a considerable increase in the power plant field, either increased electric load on central stations for operating motor-driven boosters or gas-engine-driven boosters in individual booster stations. As with oil pipe lines, internal combustion engines were first used because of the proximity of fuel but motor-driven pumps and boosters are rapidly forging ahead. Whatever source of power is used, long distance gas transmission will increase and broaden the power field.

WHEN PURCHASING coal, the only heat value that is of interest to the operator is that based on the commercially moist sample. The use of heat determinations on a dry basis has become quite general and often leads to confusion and misjudgment of coal values to those buyers not familiar with coal analysis.

Although there is chance for considerable error in sampling methods, coal analysts themselves are quite accurate and different determinations should agree if the sample has been properly prepared and quartered. According to the A. S. T. M., the permissible variation of determinations in one laboratory should not exceed 0.3 per cent and of different laboratories, 0.5 per cent on the same sample.

Power Plant Engineering Developments and News

Boiler Blowdown Meter

MEASURING boiler blowoff helps materially in maintaining high boiler economy. If the blowoff valve leaks, an enormous amount of hot water may be wasted; similarly if the men are careless in handling the blowoff valve. On the other hand, if the blowdown is insufficient or irregular, trouble from priming and foaming follows, due to over-concentration of impurities in the boiler feedwater. A reliable boiler blowdown meter,

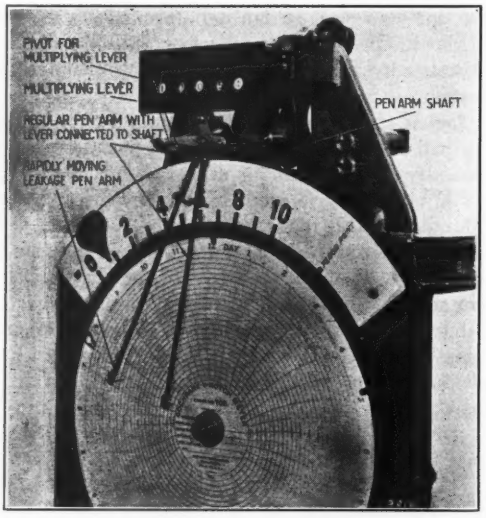

PIVOT FOR MULTIPLYING LEVER
MULTIPLYING LEVER
REGULAR PEN ARM WITH LEVER CONNECTED TO SHAFT
RAPIDLY MOVING LEAKAGE PEN ARM
PEN ARM SHAFT

FIG. 1. BLOWDOWN RECORDER WITH LEAKAGE PEN ACTUATED FROM MAIN PEN BY MULTIPLYING MECHANISM

however, gives a continuous record of both frequency and amount of blowoff valve discharge, including leakage and regular blowdowns. This information is further indispensable in calculating heat balances and efficiencies.

Leakage is so slight in comparison with the rate of flow when blowing down the boiler that it would hardly show upon the chart used to record the regular blowoff. An additional pen and special multiplying mechanism are therefore used in the Cochrane boiler blowdown recorder, Fig. 1, to record the leakage flow upon a magnified scale. As may be seen from the accompanying sketch, an arm connected to the regular pen bears upon a level, which in turn bears upon an arm attached to the leakage pen, the multiplying lever being held in engagement with the pen arm lever by a counterbalance. The transmission has a 10-to-1 ratio; that is, the leakage pen travels entirely across the chart while the regular pen is moving from 0 to 1. When the leakage pen has crossed the chart, however, it strikes a stop and remains in contact with the latter, although the flow may continue to increase, which fact will be recorded by the regular pen. When the flow again falls to less than 10 per cent of maximum, the leakage pen comes into action again for the range from 10 per cent to zero.

Water issuing from the blowoff valve of a boiler under high pressure not only has a high velocity but also forms a large volume of steam, which causes the water to be ejected from the blowoff pipe with considerable violence. A substantial blowoff tank must therefore be provided to receive this water and means must

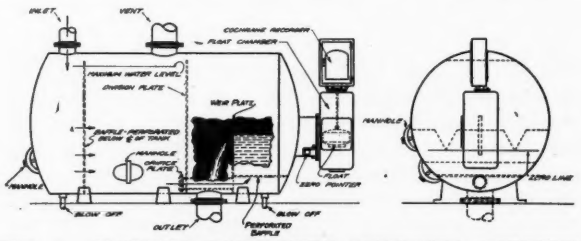


FIG. 2. BLOWOFF TANK WITH RECORDER, SHOWING INTERNAL ARRANGEMENTS

be used to prevent the disturbances set up therein from influencing too much the water in the V-notch meter chamber. Furthermore, the blowoff tank should have sufficient storage capacity so that, although a large volume of blowoff may be received in a short period of time, the water will run off through the meter more leisurely and uniformly.

In the Cochrane Combined blowoff tank and meter, Fig. 2, the blowoff is first received in a compartment at one end, which communicates through a perforated baffle with a larger storage or receiver space, the latter being formed in a horizontal cylindrical shell, which gives large storage with comparatively small change in head. An opening in the top of the storage chamber provides for the escape of the vapor or steam liberated in the blowoff chamber. This vapor can, if desired, be led to a feedwater heater or utilized in other ways.

Blowoff water flows from the receiver chamber through a large pipe to the still-water chamber of the V-notch weir and after passing over the weir is received in an out-flow chamber, from which it is drained to the point of ultimate disposal. All chambers are provided with suitable sludge discharge openings.

The still-water chamber communicates with an outside recorder float chamber by a high, narrow channel, which assures equality of level between the still-water

chamber and the float chamber, while at the same time preventing disturbances in the still-water chamber from acting directly upon the float and also assuring that the temperature of the water in the float chamber will, through radiation, be somewhat lower than the temperature of the water in the still-water chamber. This prevents flashing of the water and formation of steam under the float in case of rapid fluctuations in pressure and temperature within the blowoff tank and meter. This feature has been found highly desirable in all V-notch meters handling hot water.

Ellison Mercury Element Pointer Draft Gage

PRESENT TENDENCY toward larger boiler units, using smaller economizers, with consequent higher gas velocities and greater drop through the boiler, has brought about a demand for draft gages with ranges far beyond the practice of the past. To meet this demand, Ellison Draft Gage Co., 214 West Kinzie St., Chicago, Ill., has developed the mercury element pointer draft gage, as shown, for readings higher than normal.

Gasometer bell of the gage is made of case-hardened and polished steel, to prevent rust and to reduce the adhesion factor to the lowest point. It is only 1 in. in diameter and operates in a well 1⅝ in. in diameter, in order to require the minimum amount of mercury. The top of the mercury bath is sealed with oil to prevent oxidation. This element, Fig 1, has been furnished for readings of 12, 16, 18, 20, 24 in. and for 1 lb., 1½ lb. and 2 lb.

For transmitting the motion of the gasometer bell to the pointer, the Ellison straight-line movement shown in Fig. 2 is employed. This converts the arc movement of the beam, actuated by the bell, into a straight line motion of a pointer tip moving over a vertical straight scale at the front of the instrument. The mechanism consists of a system of correlated levers with inverse incremental gravity loading, designed to be mathematically correct in relationship and to provide a pointer movement that gives a true arithmetical indication of the actuating pressure over the entire range of a straight-line scale of uniform spacing.

Pointer arm is of light sheet brass in channel form, 12 in. long; fulcrum knife edges are of steel, case-hardened and honed, operating in brass V bearings. Fulcrum and bell knife edges are insured against displacement by removable straps and stops are provided to limit high and low beam travel. Casing is of a sheet iron highly resistant to corrosion and well-stiffened with angle irons and channels and all parts of the instrument are ruggedly and carefully made to assure accuracy, dependability and excellent visibility.

Improvements in Riley Atrita

SEVERAL IMPORTANT changes, it is announced, have been made to improve reliability and efficiency of the Riley Atrita unit pulverizer. Recent refinements, it is claimed, make it pulverize finer, consume less power and capable of higher capacities. The most important improvements have been obtained by changes in the pulverizing chamber. The outer casing has been increased in size to accommodate a heavy steel band in the shape of a horseshoe. This band is entirely separated from the casing, except where it is supported at the two ends. To the steel band are bolted castings designed not only to take the wear but because of their shape, to have an important part in the pulverizing process. These castings are of a size easily handled. Where the most severe service takes place, they are made of a special wear resisting material. Figure 1 shows a band taken out of the machine and several of the small castings removed from it. The saw tooth shapes of these castings are intended to break up the circular motion of the coal and primary air and by so doing to reduce the amount of energy wasted in revolving the mass of coal against the periphery of the grinding chamber.

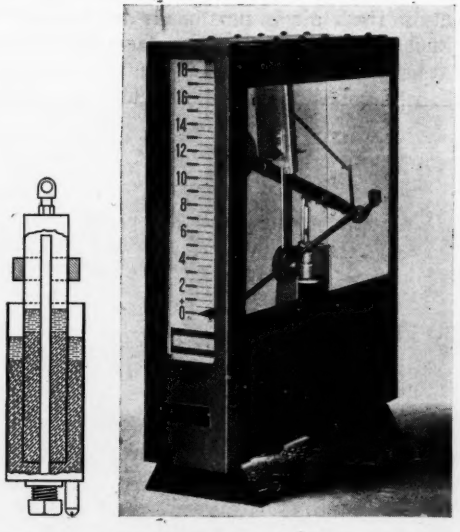


FIG. 1. (LEFT) MERCURY ELEMENT OF NEW GAGE HAS GASOMETER BELL OF CASE-HARDENED STEEL. FIG. 2. (RIGHT) VIEW OF COMPLETE GAGE, SHOWING STRAIGHT-LINE MOVEMENT

FIG. 1. STEEL BAND WITH SAW TOOTH CASTINGS

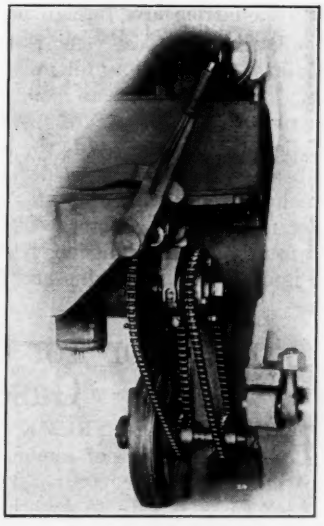


FIG. 2. TWO-SPEED FEEDER DRIVE

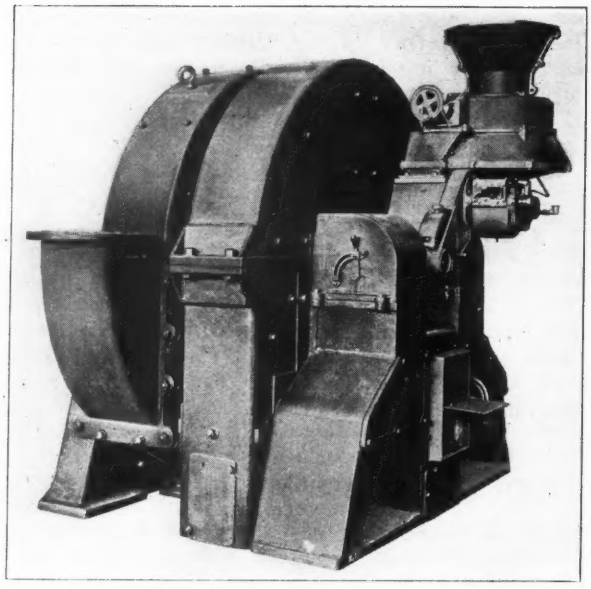


FIG. 3. NO. 5 ATRITA, WITH ELECTRICALLY WELDED STEEL HOUSING, IS RATED AT 7500 LB. PER HR.

For the main bearings, the SKF railway type of mounting has been adopted. This consists of a roller bearing using a tapered sleeve between the inner race and the shaft, to insure accurate fit and to prevent movement of the inner race of the bearing in relation to the shaft.

Feeder drive has been improved, particularly in regards to the two-speed clutch. This clutch has been changed from the countershaft to the relatively slow-speed worm shaft. The clutch has been increased in size with correspondingly large contact surfaces. The clutch shifting mechanism, Fig. 2, is designed to prevent overtraveling, that is, in disengaging, the clutch shaft has a positive neutral stop.

Magnet of the self-contained magnetic separator has been redesigned to provide a more rugged unit. The entire magnet has been enclosed in a brass housing with only the poles exposed, to protect the windings against abrasion from any foreign material.

During the past year, there has been designed and built a No. 5 Atrita unit pulverizer with rated capacity of 7500 lb. of coal an hour and a greater maximum capacity than that figure. Design of the No. 5 machine follows that of the No. 4; the housings are made entirely of steel, electrically welded, and the entire unit is mounted on a cast iron sub-base, extended to provide for mounting the motor. The feeder is equipped with a four speed transmission, providing four rates of feed. Figure 3 shows machine and feeder drive.

Indicator for Combustible Gases

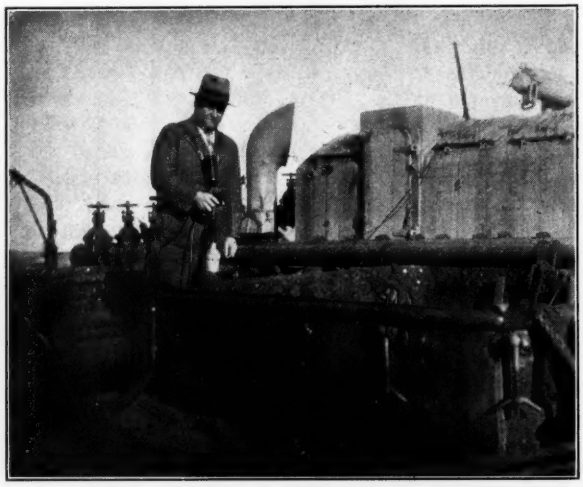
PORTABLE INSTRUMENT to detect the presence of a wide range of combustible gases or vapors and to indicate whether or not the atmosphere containing these gases is safe to breathe and safe for flames or fire, is being placed on the market by The Union Carbide Sales Co., 30 East 42nd St., New York City. The U.C.C. Combustible Gas Indicator utilizes the effect of combustion or flammable gas and air mixtures on the surface of a heated filament. This combustion increases the temperature and, consequently, the electrical resistance of the filament. This change in resistance causes the needle of a meter to move over a scale, from which the desired information relative to gas conditions is obtained.

This indicator comprises the following parts: detector head or combustion chamber; meter case; portable storage battery.

Detector head consists of a cylindrical metal case or bonnet which screws onto a metal base equipped with a short carrying handle. The bonnet is provided with louvres or small openings to permit the atmosphere being tested to circulate about the heated filament. Within the bonnet are three concentric gauze screens, of a type similar to those used in flame safety lamps, to prevent the ignition of an external gas and air mixture. In the center of the chamber formed by these screens is the filament cartridge. The detector head is so constructed that accidental incorrect assembly of safety screens and filament cartridge renders the circuit inoperative. A flexible twin conductor cable about 50 ft. long connects the detector head with the meter case. The meter case contains the various resistances in the detector circuit, the indicating meter, the control switch and a rheostat. A short flexible cable connects the meter case to the portable storage battery which supplies the power to operate the indicator.

The storage battery is carried on a leather belt worn around the waist. To this belt are hooked the detector head and the coiled cable. The meter case is carried by a light strap around the operator's neck, or it may be hooked onto the leather battery belt if so desired. The entire outfit is compactly stowed in a carrying case from which it may be operated, without removing the meter and battery from the case, if preferred.

The indicator is made ready for operation by throwing the control switch first to the Filament position, then a few seconds later to the Meter position. Zero adjustment in fresh air is next made by turning the rheostat knob. The operator then places the detector



U.C.C. COMBUSTIBLE GAS INDICATOR IS ENTIRELY PORTABLE

head in the atmosphere to be tested and reads the meter. The detector head may be held in the hand, raised vertically or extended horizontally on a pole, or lowered by the cable into a manhole, tank, or elsewhere.

For the operator who desires to know the amount in per cent of a known combustible gas present in a mixture of that gas and air, the meter scale reading is taken and then referred to the particular curve or chart prepared for that gas. From the curve chart, the operator reads directly the per cent of gas present corresponding to the scale reading of the meter. If an unknown mixture of flammable gases exists and the operator desires to know whether or not the mixture is explosive, the meter scale reading is taken and referred to a "per cent of explosibility" curve.

Especially for those concerned with gas testing in and about oil tankers, oil and gasoline storage tanks, tank cars, oil refineries and the like, the scale is also divided into a white section and a red section. If the meter needle comes to rest anywhere in the red section, an atmosphere containing 0.2 per cent or more of combustible gas (expressed as pentane vapor) is indicated showing that the atmosphere is unsafe to breathe without gas masks and unsafe for any work that requires heat or fire, or is liable to emit sparks. If the meter needle comes to rest in the white section, less than the equivalent of 0.2 per cent of pentane is present and hot repair work may be done, provided that all other regulations and precautionary measures have been followed.

Automatic Control of Blowdown

SPRING-LOADED safety valves are usually set for a 4 per cent blowdown after popping, which means that, at 600 lb. pressure, the drop is 24 lb. before the valve closes, with attendant waste of steam.

To reduce blowdown, the Ashcroft Power control valve is designed to open at a lower pressure than any of the other safety valves and close with one per cent drop in pressure, permitting a more even rate of steaming of the boiler.

Operation of the control valve is by means of an automatic control box, having a double Bourdon tube with tips held against stops by adjustable tension spring. The tension on this spring regulates the pressure at which the control opens the valve.

In place of the usual steam gage pointer, a lever is operated by the Bourdon tubes so as to close an electrical contact at its end, thus actuating a relay which passes current to a solenoid to operate the power control valve. As pressure drops, the contact lever moves over and, at a pressure determined by the space between contacts, which is adjustable, the blowdown contact is made and the relay actuates the solenoid to close the power control valve. Thus opening pressure and amount of blowdown can be adjusted at the boiler control board, usually to about 4-lb. blowdown.

Outside the box is a switch which can be thrown to automatic, off or blow positions for testing the action of the control valve.

Details and operation of the power control valve are shown in Fig. 2. Steam is admitted at A and passes around the outlet B to the chamber above. It enters chamber D through passages C, thus holding the valve 7 to its seat. When the solenoid is actuated, it pulls down the lever, opening spring-loaded valve 14, thus relieving pressure in chamber D, when steam pressure on ring surface E which has an area the difference between the seat, 3 in. diam. and the piston 9, 4 in. diam., forces the valve 7 open and allows steam to blow. When current is reversed, the solenoid plunger rises, valve 14 is closed and held in that position by the spring and pressure rises in D, forcing valve 7 to its seat.

Usually in a superheat boiler, the control valve is actuated by steam drum pressure to blow at 5 lb. below

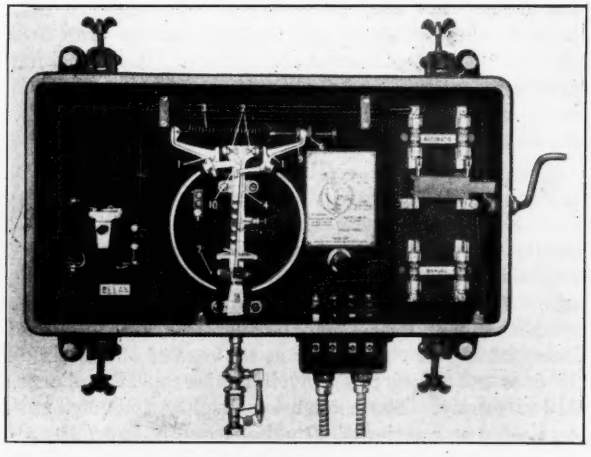


FIG. 1. AUTOMATIC CONTROL BOX ACTUATES SOLENOID OF POWER CONTROL VALVE

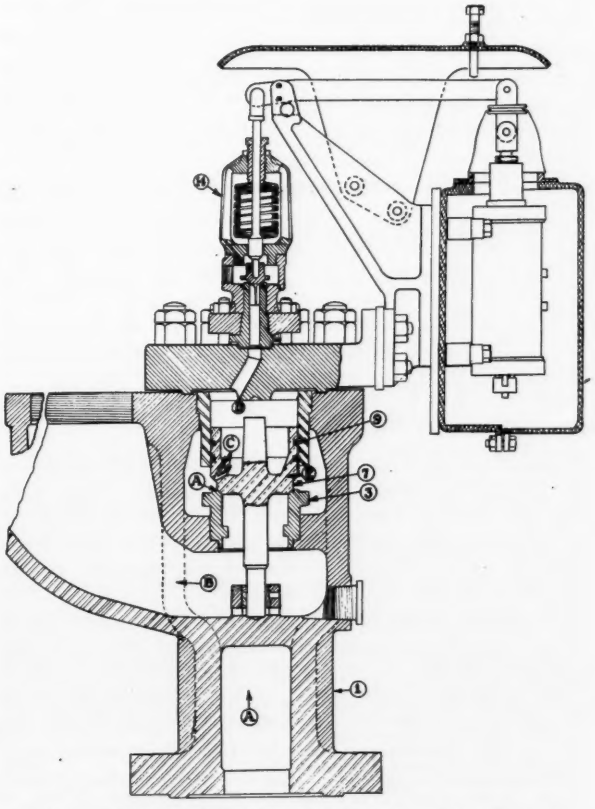


FIG. 2. POWER CONTROL VALVE OPERATES ON 4 LB. BLOWDOWN

the lowest safety valves but the control box may be operated by superheater pressure if preferred.

For the standard valve with 3 in. diam. seat, the capacity at 600 lb. pressure is 187,000 lb. of steam an hour. Smaller capacity is secured by reducing the lift. The standard is for pressures to 800 lb. and temperatures to 800 deg. F. but the valve can be designed for higher pressures and larger capacities. It is made by Consolidated Ashcroft Hancock Co., Inc., 100 E. 42nd St., New York City.

A.I.E.E. Plans Diversified Program for Summer Meeting

FOR THE SUMMER convention of the American Institute of Electrical Engineers to be held at the New Ocean House, Swampscott, Mass., June 24-28, a diversified program of technical papers and many interesting trips have been arranged. The business sessions will begin on Tuesday morning with address by Governor Allen of Massachusetts. At 8:00 p. m. of the same day, Dr. Harlow Shapley, director of Harvard College Observatory, will deliver the convention lecture. On Thursday an all-day trip will be made to Rye Beach, Maine. The final technical sessions will be held on Friday morning and in the afternoon a post-convention excursion through the White Mountains will start at 3:00 o'clock. Among the papers scheduled are the following:

DISTRIBUTION AND POWER GENERATION

Symposium on "Synchronized at the Load"

a. Fundamental Plan, A. H. Kehoe, United Electric Light and Power Co.

b. Theoretical Calculations of System Behavior, S. B. Griscom, Westinghouse Electric & Mfg. Co.

c. System Tests and Operating Connections, H. R. Searing and G. P. Milne, United Electric Light & Power Co.

Automatic Substations of Edison Electric Illuminating Co. of Boston, W. W. Edson, Edison Elec. Ill. Co. of Boston.

Rehabilitation and Rebuilding of Steam Power Plants, C. F. Hirshfeld, Detroit Edison Co.

Application of Induction Regulators on A.C. Distribution Networks, E. P. Wolfert and T. J. Brosnan, Westinghouse Electric & Mfg. Co.

TRANSPORTATION

Electrification of the Mexican Railway, J. B. Cox, General Electric Co.

Contact-Wire Wear on Electric Railroads, I. T. Landby, Illinois Central Railroad Co.

An Electrified Railroad Substation, J. V. B. Duer, Pennsylvania Railroad.

D.C. Railroad Substations, A. M. Garrett, Commonwealth Edison Co.

MISCELLANEOUS

High-Frequency Portable Electric Tools, C. B. Coates, Chicago Pneumatic Tool Co.

Electrical Wave Analyzers for Power & Telephone Systems, P. G. McCurdy and P. W. Blye, American Tel. & Tel. Co.

Telephone Transmission Reference Systems, W. H. Martin, American Tel. & Tel. Co.

Design of Electric Heating Elements, Edwin Fleischmann, The Niagara Falls Power Co.

ELECTRICAL MACHINERY

Safe Loading of Oil-Immersed Transformers, E. T. Norris of Ferranti, Limited.

Induction Motor Operation with Non-Sinusoidal Impressed Voltages, L. A. Doggett and E. R. Queer, Pennsylvania State College.

Outdoor Hydrogen-Ventilated Synchronous Condensers, R. W. Wieseman, General Electric Co.

Short-Circuit Torque in Synchronous Machines without Damper Windings, G. W. Penney, Westinghouse Elec. & Mfg. Co.

Analytical Determination of Magnetic Fields, B. L. Robertson and I. A. Tarry, General Electric Co.

SHIELDING IN ELECTRICAL MEASUREMENTS

Shielding and Guarding Electrical Measuring Apparatus, H. L. Curtis, Bureau of Standards.

Some Problems in Dielectric Loss Measurements, C. L. Dawes, P. L. Hoover and H. H. Reichard, Harvard University.

Shielding in High-Frequency Measurements, J. G. Ferguson, Bell Telephone Laboratories.

Shielding of Cables in Dielectric Loss Measurements, E. H. Salter, Elec. Testing Laboratories.

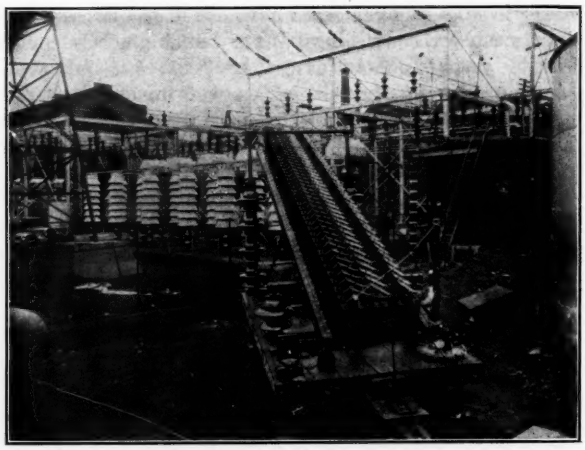
Precautions against Stray Magnetic Fields in Measurements with Large Alternating Currents, F. B. Silsbee, Bureau of Standards.

Magnetic Shielding in Electrical Measurements, S. L. Gokhale, General Electric Co.

1,000,000 V. Out in the Field but Under Absolute Control

ARTIFICIAL LIGHTNING of 1,000,000 v. repeatedly struck the 66,000-v. transmission line of the Turner Falls Power and Electric Co. at Pittsfield, Mass., on a recent Sunday morning. No damage was caused to the lines, however, for the lightning arrester engineers of the General Electric Co., in charge of the tests, knew in advance when the flashes would occur and were prepared with adequate apparatus for protecting the lines.

It was the first time that artificial lightning had been hurled into a high-tension line under full voltage and likewise was the first time the new portable 1,000,000-v. generator built at Pittsfield had been used. The generator has now been sent out for testing public utility transmission lines in various parts of the country.



LOOKING ALONG THE 1,000,000-V. PORTABLE LIGHTNING GENERATOR TOWARDS THE TRANSMISSION LINE

"The purpose of this new portable lightning generator and the tests such as we have been making is to find out whether high-voltage transmission lines are adequately protected against natural lightning," said K. B. McEachron of the General Electric Co., in charge of the tests. "Every transmission line has its lightning arresters and other protective devices, but often it is not known how well protected the line may be until it is struck by lightning. Serious damage may then occur if the protection was not sufficient. With this new generator we can make tests at any place, doing the work on Sundays or other times when heavy demands are not being made on the transmission systems."

Use of the million-volt generator on the 66,000-v. line under full voltage was an extension of the work of the same engineers who some months ago, with a smaller field generator, experimented with 200,000-v. artificial lightning bolts on the same lines without voltage.

Million-volt flashes can be shot into a transmission line with the new generator at the rate of one a minute. It does not require high voltage for operation, using 110-v. supply. The condensers—eighty 25,000-v. units connected as a series of 40 pairs—rapidly build up voltage and then discharge in rapid succession to give the 1,000,000-v. flash.

Artificial lightning generators capable of producing 500,000 v. were made years ago and of 1,000,000 v. shortly thereafter; now the peak has been increased to 5,000,000 v. in the laboratory. Work with actual lightning on high-voltage transmission lines was started two years ago, and, during a thunderstorm in the Alleghenies last July, General Electric engineers obtained a cathode-ray oscillogram showing the effects of a 2,500,000-v. lightning stroke on transmission wires. Having obtained such a record, it became possible for engineers to duplicate the stroke with laboratory equipment.

News Notes

JEFFREY MANUFACTURING Co., Columbus, Ohio, announces the incorporation of the Jeffrey Manufacturing Co., Ltd., at Montreal, Canada. The new company has its head office and works in Montreal, a branch office in Toronto and a mining supply warehouse in Calgary, Alberta. The Jeffrey Manufacturing Co. also acquired recently the Galion Iron Works and Manufacturing Co. of Galion, Ohio. Products of both the Jeffrey and Galion Companies will be handled by the Jeffrey Manufacturing Co., Ltd. in Canada. Officers of the new company are R. W. Gillispie, president, R. H. Ross, treasurer and manager, F. N. Diehl, secretary.

MURRAY IRON WORKS Co., Burlington, Iowa, has recently placed on the market a small steam turbine designed for use with unit heaters and states that it has made a number of successful installations of these units. The turbine exhausts its steam to the coils of the unit heater and thus, it is claimed, the power for driving the fan is obtained at extremely low cost. The turbine is generally arranged so that it will consume for power about two-thirds of the steam required for the heater element. The remaining one-third of the steam is bypassed through the turbine by a valve provided especially for this purpose. The turbine is provided with a separate speed control valve.

MILWAUKEE ELECTRIC RAILWAY & LIGHT Co., Milwaukee, Wis., has placed a contract with the Allis-Chalmers Manufacturing Co. for a steam turbine unit to be installed in its Lakeside power station in Milwaukee. This unit is rated at 60,000 kw. and will be of the straight reaction, single-cylinder, single-generator type with direct-connected exciter. The turbine is designed for normal operating steam pressure of 290 lb. gage and a temperature of 700 deg. F. Electrical characteristics of the unit are 13,800 v., 60-cycle, 3-phase, 1800 r.p.m. The exciter has a capacity of 200 kw. The turbine unit will be manufactured at the West Allis Works of the Allis-Chalmers Manufacturing Co. and the equipment is to be installed ready for operation by September 1, 1930.

AT A DIRECTORS' MEETING in New York City on May 27, J. S. Tritle, in charge of manufacturing operations of the Westinghouse Electric & Manufacturing Co., was made a vice-president. A native of Nevada and a Yale graduate, Mr. Tritle has been connected with the electrical industry since 1893. After managing the Kansas City and St. Louis district sales offices for a number of years, in 1922 he was made manager of the merchandising department. In 1925 he assumed full charge of the engineering and manufacturing as well as sales work of the merchandising division, with headquarters at Mansfield, Ohio. On May 1, 1929, when Vice-President H. P. Davis was assigned to devote his entire time to the rapidly-growing activities of the company in the radio field, Mr. Tritle assumed responsibility and authority for manufacturing operations of the entire company.

H. S. BRADLEY, president of The Lagonda Manufacturing Co., of which he had been the head for 31 yr., died at the age of 76 at his home in Springfield, Ohio, on May 15, 1929. He had been the head of The Lagonda Manufacturing Co., which he established in 1898, when he developed a boiler tube cleaner. Previous to that time, he had served as secretary of the Foos Manufacturing Co. for 16 yr.

FULLER LEHIGH Co., Fullerton, Pa., moved its New York office on April 27 from 50 Church St., to 85 Liberty St.

BROWN INSTRUMENT Co., Philadelphia, Pa., has moved its Boston office from 161 Devonshire St. to 1107 Public Service Building, 89 Broad St., Boston, Mass. The Pittsburgh office of the company has moved to new quarters at 1522 Oliver Building.

ELLIS CLARK SOPER announces resumption of the practice of his profession of consulting engineer, with offices at 17 East 45th St., New York, N. Y.

AMERICAN ENGINEERING Co., Philadelphia, Pa., announces that the Pittsburgh office of its Taylor Stoker Division is now located at 2147 Oliver Building, Pittsburgh, Pa.

GENERAL REFRACTORIES Co., Philadelphia, Pa., has appointed Woodward & MacMillan, Edificio Metropolitana, Havana, Cuba, as sales agent for Cuba and various countries in Central America.

ELECTION OF HAROLD L. GEISSE as vice-president of Wisconsin Valley Electric Co., Wausau, Wis., has recently been announced.

JOHNS-MANVILLE CORP., New York City, announces the removal on May 1 of its Western Division headquarters from South Michigan Avenue and 18th St., to the new Carbide and Carbon Building, 230 North Michigan Ave., Chicago, Ill.

IDEAL COMMUTATOR DRESSER Co., Sycamore, Ill., announces that its eastern office and warehouse has been moved to 18 Warren St., New York City. It will be in charge of R. W. Becker, eastern division manager and E. J. Dreyfuss, New York district manager.

QUIGLEY FURNACE SPECIALTIES Co., Inc., has moved to new headquarters at 56 West 45th St., New York City.

AT A RECENT MEETING of the Board of Directors of the Timken Roller Bearing Co., Canton, Ohio, Marcus T. Lothrop was elected president of the company, succeeding H. H. Timken, who becomes chairman of the board. Mr. Lothrop joined the Timken Roller Bearing Co. in 1911 as metallurgist and, for the past 18 yr., has occupied various positions in the work of metallurgy, research and operations. For the past few years, he has been vice president and general manager in charge of all operating and sales. Other officials elected were: W. R. Timken, J. G. Obermier, J. W. Spray, T. V. Buckwalter, H. J. Porter, vice presidents; and J. F. Strough, secretary-treasurer. Judd W. Spray, who has been with the company 14 yr., and vice-president and general sales manager since 1928, was made one of the

directors at the recent annual stockholders meeting. All of the previous members of the board of directors were reëlected and A. C. Ernst of Cleveland, Ohio, was newly elected.

YEOMANS BROTHERS Co., Chicago, announces the appointment of the Capitol Equipment Co., Bank of Commerce Building, Charleston, West Virginia, to represent it in the Southwestern part of that state.

W. P. THOMAS, formerly secretary, has been elected vice-president of the Diamond Power Specialty Corp., Detroit, Mich.

PENNSYLVANIA PUMP & COMPRESSOR Co., Easton, Pa., has appointed Carpenter & Byrne, 4 Smithfield St., Pittsburgh, Pa., as its sales representatives in the Pittsburgh district.

UNION IRON WORKS, Erie, Pa., announces that its Chicago office, in charge of C. B. Adams, has moved to new quarters in the 333 North Michigan Avenue Building, Chicago, Ill.

AIR PREHEATER CORP., New York City, has recently opened an office at 616 Tacoma Building, Tacoma, Washington.

EDISON ELECTRIC ILLUMINATING Co., Boston, Mass., has negotiations under way for the purchase of the Concord, New Hampshire municipal power plant for which it has tendered an offer of $600,000.

NEIL C. HURLEY and J. F. Roche, operating as a company known as the Chicago Utilities Corp., have purchased and taken over the management of the newly reorganized Binks Manufacturing Co., formerly known as the Binks Spray Equipment Co., Chicago, Ill.

AT THE ANNUAL MEETING of the American District Steam Co., North Tonawanda, N. Y., on April 16, the following officers were elected: president and treasurer, Robert Hall; vice president, N. D. Fish; secretary, George H. West; assistant treasurer, H. C. Jagow.

IDEAL COMMUTATOR DRESSER Co., Sycamore, Ill., has recently placed on the market a tool for stripping wire known as the E-Z Wire Stripper. This is designed to be always ready for use, requiring no setting. In operation, it is designed to clamp the wire, cut the insulation and strip it automatically with one squeeze on the handles. When the pressure is released, the handles open, resetting the stripper for the next operation. The tool is designed to protect both the operator's hands and the wire. Cutting edges are shielded and the blind centers of the V notches on the blades prevent cutting or scarring of the wire. Standard models strip from 10 to 20 gage solid core or stranded wire and can be converted to handle larger sizes by enlarging the holes.

EL PASO ELECTRIC Co., El Paso, Texas, is planning a new steam electric generating plant on the Rio Grande River about four miles from the business district. Contract has been awarded to the Westinghouse Electric & Manufacturing Co. for two turbine generating units with a total capacity of 40,000 kw. and to the Babcock and Wilcox Co. for water-tube boilers. Contract has been let to the Virginia Bridge & Iron Co., Roanoke, Va., for structural steel for the building. The El Paso Electric Co. is a subsidiary of the Engineers Public Service Co., an interest of Stone & Webster, Inc., Boston, Mass. Plans for the station will be carried out by Stone & Webster Engineering Corp.

AT A RECENT MEETING of the Board of Directors of E. F. Houghton & Co., Philadelphia, Pa., Louis E. Murphy was elected president to succeed the late president, Charles E. Carpenter. A. E. Carpenter was elected first vice-president and treasurer and George W. Pressell was elected second vice-president and secretary.

W. J. DANA, Professor of Experimental Engineering at North Carolina State College of Agriculture and Engineer, will spend the coming summer in the mechanical engineering department of Columbia Engineering & Management Corp., Cincinnati, Ohio. This will be his second summer with this organization, in which his work consists of power plant checking and design.

FRANK W. HOYT, who has for some years been associated with Nat. D. Stevens at Wilkes-Barre, Pa., in the sale of power plant equipment, is representing The Edward Valve & Manufacturing Co. in the anthracite coal section, with offices in the Markle Bank Building, Hazleton, Pa. Mr. Hoyt is now associated with the Coxe Stoker Engineering Co.

PROFESSOR A. G. CHRISTIE of Johns Hopkins University sailed on June 12 to spend a third consecutive summer as consulting engineer for British interests.

UNIVERSITY OF BALTIMORE, College Park, Baltimore, Md., has plans under way for the construction of a one-story steam power plant for central heating service, reported to cost close to $200,000, with equipment. Smith & May, Calvert Building, Baltimore, Md., are architects.

Books and Catalogs

INTRODUCTION TO COLLEGE PHYSICS. By C. M. Kilby, 350 pages, 358 illustrations, 6 by 8 in.; cloth, $3. D. Van Nostrand Co., New York, 1929.

Prepared as a short course on the fundamentals of Physics for students who wish an elementary knowledge or as a preliminary to further study, this book starts with clear definitions and builds up to a knowledge of simple problems. Many of these are given for solution to test the student's knowledge and show the application of principles. The usual order is followed of treating Mechanics, Magnetism and Electricity, Heat, Sound and Light with equations worked out embodying the laws of each subject. Knowledge of algebra and plane geometry is assumed. Demonstrations for class or individual use are suggested, the author seeking to produce a book which will be clear and concise so that the student will need no assistance and not find the study "hard." Principles are fully illustrated by diagrams and curves, the details of apparatus being left for laboratory demonstration.

INVESTIGATION OF WARM AIR FURNACES AND Heat Systems, Part III. By Arthur C. Willard, Alonzo P. Crafts, Vincent S. Day. Published by the Engineering Experiment Station, University of Illinois, Urbana, Ill., as bulletin No. 188; 80 pages; price, 45c.

The fifth report of the series of investigations being carried on by the University of Illinois and the National Warm Air, Heating and Ventilating Association on warm air furnaces and furnace heating systems.

REPORT OF THE ENGINEERING FOUNDATION for the year ended February 21, 1929, has recently been issued as Publication No. 17 by the Engineering Foundation, 29 West 39th St., New York City. The report contains data on the organization of the Engineering Foundation, review of the year's activities, including such items as Arch Dam investigation (previously referred to in the news columns of Power Plant Engineering) as well as investigation of fluid flow, alloys of iron and many other subjects, and data on the participation of the Foundation in the steam research that is now being carried on. Financial statement is given, together with many other details regarding the conduct of the Engineering Foundation.

NEW DEVELOPMENTS IN ELECTRICAL MEASURING DEVICES is the title of a recent serial report of the Meter Committee, Engineering National Section of the National Electric Light Association, 420 Lexington Ave., New York City. Description is given of many new types of meters, such as single-phase watthour meters, polyphase watthour meters, volt-amperehour meters, load totalizing meters, instrument transformers, frequency meters and other graphic instruments. Data on these are presented by the manufacturers of the various devices.

POWER PLANT Instrument Data Book is the title of an interesting publication received from the Brown Instrument Co., Wayne and Roberts Aves., Philadelphia, Pa., which shows the records that it is desirable to have in a power plant, how easily these may be maintained and how the data thus secured should be used. The various parts of the plant are considered under the headings: fuels, combustion, steam generation, prime movers, feedwater system, condensing system, auxiliaries, electrical system. A center spread in the book gives a diagram of the power plant with the points at which instruments to maintain records may be used to advantage. Discussion is given of the types of instruments, their proper location and the applications of each type. The book is fully and completely indexed for quick reference.

OIL-POWER, a monthly publication of the Standard Oil Co. of New York, in its April, 1929 issue, has an interesting article on the development of the steamship, entitled, "What happened before the Clermont," telling how Fulton's name ended, rather than began, the honor roll of pioneers who produced the steamboat.

HOW HOT IS HOT? In a recent four-page folder, the Foxboro Co., Foxboro, Mass., explains how you can find out with Foxboro indicating, recording and controlling instruments.

CHICAGO PNEUMATIC M. W. M. Benz Diesel Engines, Type R. H. 75, are described in Bulletin 775 by Chicago Pneumatic Tool Co., New York. Complete details of the component parts of the engine are shown with discussion of their principal features.

IN A 12-PAGE illustrated bulletin, Southwark Foundry and Machine Co., 400 Washington Ave., Philadelphia, Pa., describes the McCollum-Peters Electric Telemeter, the Whittemore Strain Gage and the Huggenberger Tensometer. The telemeter, described some time ago in Power Plant Engineering, is made under contract with Emery-Tatnall Co. and is designed to measure forces in members of all types of structures, both stationary and moving, such as concrete structures, railroad structures, air craft, automotive engines and so on. The Whittemore strain gage is designed to measure stresses in structures and the tensometer is another form of strain gage manufactured by Huggenberger of Zurich, Switzerland. The bulletin contains many interesting photographs of the ways in which these instruments are used for determining strains and stresses in engineering structures.

DRACCO HIGH-VACUUM PNEUMATIC CONVEYORS are described and illustrated in Bulletin No. 501 by the Dust Recovering & Conveying Co., Harvard Ave. and East 116th St., Cleveland, Ohio.

MEETING YOUR IDEAS on the Flow Problem, an illustrated 12-page bulletin, gives the requirements that are often demanded in a flow meter and shows how the Brown flow meter fulfills these requirements. The bulletin is published by the Brown Instrument Co., Wayne & Roberts Ave., Philadelphia, Pa.

REDUCING THE COST of Boiler Operation with Filtrators is discussed in a recent 18-page, well-illustrated bulletin by Filtrators Co., Inc., 96 Liberty St., New York. The Filtrator employs flaxseed to form a colloidal solution for the treatment of boiler feedwater, the flaxseed emulsion being designed to coat with a film all particles of solid matter suspended in water and to prevent them from adhering to each other or to surfaces of the boiler.

SULLIVAN ANGLE-COMPOUND AIR COMPRESSORS, direct connected to Diesel engines, are described in bulletin No. 83-L issued by Sullivan Machinery Co., 122 S. Michigan Ave., Chicago, Ill. Advantages of Diesel engine drive for these compressors are discussed and many data and illustrations are presented showing actual applications.

MODERN FURNACE DESIGN is discussed in catalog No. 151 by American Arch Co., Inc., 17 E. 42nd St., New York City. This describes the American sectionally-supported, air-cooled walls and suspended arches, shows how they are applied to various types of boilers and discusses the results that have been obtained by their use. The bulletin contains 48 pages and is well illustrated with line drawings showing the details of the blocks and methods of suspension.

"EFFECTIVE LIGHTNING PROTECTION" is the title of a revised 20-page circular recently published by the Westinghouse Electric and Manufacturing Co. This circular gives complete information on the nature and magnitude of transient voltages on electric systems, lightning arrester requirements and applications. The information is arranged in a convenient form and in chronological order; in fact, there is a running synopsis of the subjects and their treatment in the margin of each page. Of special interest is the information on oscillograph studies of lightning phenomena and the economic value of lightning protection. The oscillograph studies described, were made by the Westinghouse Co. in the Tennessee Mountains on a 154-kv. line of the Knoxville Power Co. The circular contains many installation views of Autovalve lightning arresters, actual oscillograms taken by the cathode ray oscillograph, and valuable charts.

President's Address Before the Sixtieth Annual Meeting of the Western Society of Engineers by

WILLIAM S. MONROE

President, Sargent & Lundy, Inc., Chicago

I want to thank the members of this society for their confidence in entrusting me to head the management of the society for the coming year. But I confess to you that I have some misgivings as to my qualifications for that kind of responsibility. I have served on the board under two very able predecessors, Major Putnam and Mr. Garcia, and I hope to be able to maintain the standards of development and growth in usefulness of the society that have been so ably carried on by these past two presidents.

Your attention has been called to the fact that we are celebrating tonight the sixtieth anniversary of the founding of our society. It is one of the oldest Engineering Associations in the United States. I hesitate to admit that its span of years is all too close to my own. But at any rate it covers no more than the years of many of our older members. It is a very short time, as history is reckoned, but it embraces practically the entire growth of the Engineering Profession as such.

Before the birth of this society engineering work, like scientific work in the earlier days, was carried on almost in secret, by only a very few individuals who by the display of exceptional innate talents and natural industry, carried forward and developed the scientific achievements of those days.

But the rapid development of scientific inventions and engineering work in the last half of the last century gave birth to our engineering schools and expanded engineering work to the dignity of a profession.

The Engineer may be broadly defined as one who applies scientific knowledge and inventive achievement to the resources available and develops them for the use and advantage of man. The engineer starts where the theoretical scientist and the inventor leave off. Of course, the dividing line is not sharply marked. There are many scientists who overlap into engineering, some engineers who end by being scientists and some who, like Thomas A. Edison and Elmer A. Sperry, combine with great distinction the two fields. But the engineers and scientists working in their respective fields are responsible for the technical development, which in the last generation has remade the world in a way that is staggering the comprehension of those who are not trained to the scientific and technical methods of thought.

It is not necessary to remind this audience of the achievements of science and engineering during the past sixty years. They have been of untold benefit to the human race and have resulted in a greater advance in civilization than has taken place in many centuries of any previous era. To mention a very few of the great achievements of this period: The electric generator and the whole development of electric power which has released mankind from all sorts of physical drudgery; the telephone, the radio, the moving pictures and now the talking pictures, which have brought entertainment and instruction to millions; the automobile, and now the flying machine which, augmenting the railroad and the steamship, are expanding by almost limitless bounds, the range of action of individuals and corporations; and there are hundreds of products of manufacture which, like rayon, were developed in the laboratories of science, have now become mechanical processes and have put the luxuries of previous ages, such as silk and fine linen, at the disposal of every one. The list could be expanded to staggering proportions but, after all, the greatest benefit that science, theoretical and applied and including engineering, has conferred upon the human race, comes from the fact that it has awakened the deductive mind. It has substituted logic and reason for dogma, investigation and analysis for prejudice. In a thousand ways it has replaced the superstitions and fears of earlier times by exact knowledge of natural phenomena. The last generation, by showing that the whole

quality and character of the life of mankind can be, as we say, remade in a lifetime, has given to the world an entirely new outlook on the future—a new meaning to the word and new possibilities to ambition. It has lifted the contemplation of the mind of man to the possibilities of immediate achievement, rather than to study of the past and reflection on the philosophies of the unknown.

And I would like to draw your attention to the fact that it is a very small number of men who are responsible for the vast amount of technical development that is going on. Dr. Arthur B. Little of Cambridge, Mass., in a remarkable address delivered in 1924, at the One Hundredth Anniversary of the Franklin Institute, "hazards the estimate that there are not in all the world 100,000 persons whose creative effort is responsible for the advancement of science." Dr. Little refers to those who are working in theoretical sciences but we can make some approximate calculations as to the number of engineers who are working in the technical applications of science. A list recently published of all the engineering societies in the United States indicates that their total membership is possibly 140,000. Many of these are duplicated in two or more societies but, if we allow for some other engineering groups and for the fact that there are some able engineers not registered in any society, the total number of men working actively at engineering in its many forms in this country, is probably not more than 150,000 and, in the countries that we include among those that make up our so-called "Western Civilization," the total would be not twice that number. Putting this with Dr. Little's estimate of 100,000 scientists, we have about 400,000 men out of a population amounting to between 300 or 400 million who are assuming the responsibility for the technical details and guiding the construction, operation and maintenance of the vast enterprises which go to make up the industrial age in which we live. On this basis they number possibly a little over one-tenth of one per cent of the population which they serve—certainly less than one-half of one per cent of the total number employed in gainful occupations.

When we reflect on its achievements we may well take pride in our profession. But there is another side to this picture on which we ought also to reflect. It is a common complaint in engineering circles that the engineer is not appreciated in proportion to his responsibilities, that his work is scarcely known nor its difficulties understood, even by those who may be intimately connected with the enterprise. It is also said that our work is taken too much as a matter of course by the public at large. And then too, there is complaint among managers and executives that engineers are too concentrated, that they have not a sufficiently broad vision—that they lack economic sense. Possibly these criticisms are all warranted. The engineer, by instinct and training *has* a concentrated type of mind. Like the scientist in his laboratory, he prefers to shut himself up with his problems, to work them out by himself or with his immediate associates. Breadth of vision, the economic sense and executive qualifications—these the engineer must acquire but they are not more difficult to achieve than technical knowledge and the engineering sense.

The field of engineering work is rapidly broadening with the increase in scientific discovery and inventive achievement. Research work, which only a few years ago was limited to the laboratories of but a few scientists working under great difficulties, is now being conducted in the elaborately equipped research laboratories of our great industries, coöperating in many cases with the laboratories of our more important technical universities, and we are only just beginning to see the possibilities of organized research. Within the last few years it has given us the perfection of the electric lamp, the wireless Trans-Atlantic telephone, the talking movie and is now well under way to develop the radio moving picture.

Civilization is changing rapidly. Old ideals, old standards and old methods are giving place to new ones in every line of activity and the changes are perhaps most rapid in engineering and industry. The general field of engineering is getting broader every year, but the work of the engineers, like the work of the scientists and like that of the older professions of law and medicine is becoming more specialized.

The Western Society of Engineers has had sixty years of active life, in the improvement of the standards of the engineering profession, and in stimulating its ideals. Our doors are open to all engineers and scientists. We wish to make this society the center of engineering activities of the great industrial community of which this city is the center. We wish to cooperate with all other engineering and scientific organizations for the proper development of the engineering profession, and for the improvement of its standards.

One of the greatest of engineers now occupies the most important executive position that this world has to offer. A new era is opening for the engineering profession. Let us be alive to its possibilities. Let us make it a new and great era for the Western Society of Engineers.

Machinery, Equipment and Supplies Used In The Production and Transmission of Power

Under the heading of each product listed will be found the names of the manufacturers of that product. The index to advertisers, next to the back cover, gives the page numbers on which the manufacturers' descriptive advertisements appear.

ACCUMULATOR, STEAM
Ruths Steam Storage, Inc., N. Y.

AIR COMPRESSORS
Allen & Billmyre Co., Inc., N. Y.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Bethlehem Steel Co., Bethlehem.
Chicago Pneumatic Tool Co., New York, N. Y.
De Laval Steam Turbine Co., Trenton, N. J.
Gardner-Denver Co., Quincy, Ill.
General Electric Co., Schenectady, N. Y.
Ingersoll-Rand Co., New York,
Nash Engrg. Co., South Norwalk, Conn.
Sullivan Machy. Co., Chicago.
Worthington Pump & Mach. Corp., New York.

AIR COOLERS
Griscom-Russell Co., New York.

AIR PREHEATERS
Air Preheater Corp., New York.
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Buffalo Forge Co., Buffalo, N. Y.
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Edge Moor Iron Co., Edge Moor,
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Detrick Co., M. H., Chicago.
Frederick Iron & Steel Co., Frederick, Md.
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BAROMETERS
Taylor Instrument Cos., Rochester, N. Y.

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BELT CONVEYORS
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Jeffrey Mfg. Co., Columbus.
Link-Belt Co., Chicago, Ill.
Stephens-Adamson Mfg. Co., Aurora, Ill.

BELT DRESSING
Dixon Crucible Co., Jos., Jersey City, N. J.
Standard Oil Co. (Indiana), Chicago, Ill.

BELTING
Quaker City Rubber Co., Phila.

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Air Preheater Corp., New York.
Carling Turbine Blower Co., Worcester, Mass.
Coppus Engrg. Corp., Worcester.
De Laval Steam Turbine Co., Trenton, N. J.
Ingersoll-Rand Co., New York,
Prat-Daniel Corp., New York.
Wing Mfg. Co., L. J., New York.

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Buffalo Forge Co., Buffalo, N. Y.
Sturtevant Co. B. F., Boston.
Wing Mfg. Co., L. J., New York.

BLOWERS, PORTABLE
Allen & Billmyre Co., Inc., N. Y.
Sturtevant Co., B. F., Boston.
Wing Mfg. Co., L. J., New York.

BLOWERS, PRESSURE
Carling Turbine Blower Co., Worcester, Mass.
Wing Mfg. Co., L. J., New York.

BLOWERS, PULVERIZED COAL
Buffalo Forge Co., Buffalo
Wing Mfg. Co., L. J., New York.

BLOWERS, STEAM
Schutte & Koerting Co., Phila.

BLOWERS, TUBE
Bayer Co., The, St. Louis, Mo.
Diamond Power Spec. Corp., Detroit, Mich.
Marion Mach., Fdry. & Supply Co., Marion, Ind.
Vulcan Soot Cleaner Co., Dubois, Pa.

BLOWERS, TURBINE
Allen & Billmyre Co., Inc., N. Y.
Carling Turbine Blower Co., Worcester, Mass.
Elliott Co., Jeannette, Pa.
Moore Steam Turbine Corp., Wellsville. N. Y.
Terry Steam Turbine Co., The, Hartford, Conn.
Wing Mfg. Co., L. J., New York.

BOILER BAFFLE CONTRACTORS
Boiler Engrg. Co., Newark, N. J.

BOILER BAFFLES
Boiler Engrg. Co., Newark, N. J.
McLeod & Henry Co., Troy, N. Y.
Quigley Furnace Spec. Co., N. Y.

BOILER BLOW-DOWN SYSTEMS
Henszey De-Concentrator Co., Watertown, Wis.

BOILER CAP CLEANERS
Lagonda Mfg. Co., Springfield, O.

BOILER COATINGS
Dampney Co. of Am., Boston.

BOILER COMPOUND
Dearborn Chemical Co., Chicago.
Garratt-Callahan Co., Chicago.
Hawk-Eye Compound Co., Blue Island, Ill.
McLeod & Henry Co., Troy, N. Y.

BOILER ENGINEERS
Boiler Engrg. Co., Newark, N. J.

BOILER FEED WATER, PURIFYING APPARATUS
Griscom-Russell Co., New York.

BOILER FRONTS
McLeod & Henry Co., Troy, N. Y.

BOILER SETTING CEMENT
Faulkner Refractories Co., J. A., Youngstown, Ohio.
Harbison-Walker Refract. Co., Pittsburgh, Pa.
Lavino and Co., E. J., Phila.,
Refractory & Engineering Corp., New York, N. Y.

BOILER SETTINGS
Ballard, Sprague & Co., Inc., New York, N. Y.
Faulkner Refractories Co., J. A., Youngstown, Ohio.
Harbison-Walker Refract. Co., Pittsburgh, Pa.
McLeod & Henry Co., Troy, N. Y.
Refractory & Engineering Corp., New York, N. Y.
Rust Engrg. Co., Pittsburgh.

BOILER TUBE CAPS
Key Boiler Equipment Co., E. St. Louis, Mo.

BOILER TUBE CLEANERS
General Specialty Co., Buffalo.
Lagonda Mfg. Co., Springfield, O.
Liberty Mfg. Co., Pittsburgh.
Pierce Co., Wm. B., Buffalo.
Roto Co., The, Newark, N. J.

BOILER TUBE PLUGS
McCarty Machine Works, Clinton, Mass.

BOILER TUBES
Boiler Tube Co. of America, Pittsburgh, Pa.
National Tube Co., Pittsburgh.
Reading Iron Co., Reading, Pa.

BOILERS
Babcock & Wilcox Co., N. Y.
Badenhausen Corp., Cornwells Heights, Pa.
Combustion Engrg. Corp., N. Y.
Connelly Boiler Co., The D., Cleveland, O.
Edge Moor Iron Co., Edge Moor,
Kingsford Fdry. & Mach. Wks., Oswego, N. Y.
Nuway Boiler & Engrg. Co., Chicago, Ill.
Springfield Boiler Co., Springfield, Ill.
Titusville Iron Works Co., Titusville, Pa.
Union Iron Wks., Erie, Pa.
Wickes Boiler Co., Saginaw.

BOILERS, HEATING
Edge Moor Iron Co., Edge Moor.
Titusville Iron Works Co., Titusville, Pa.

To Find the Manufacturers' Advertisements of Products Listed Here, See Index Page 168

BOILERS, RETURN TUBULAR
Erie City Iron Works, Erie, Pa.

BOILERS, SEMI-PORTABLE
Erie City Iron Works, Erie, Pa.

BOILERS, WASTE HEAT
Babcock & Wilcox Co., The, N.Y.
Edge Moor Iron Co., Edge Moor.
Erie City Iron Works, Erie, Pa.
Wickes Boiler Co., Saginaw.

BOILERS, WATER TUBE
Babcock & Wilcox Co., The, N.Y.
Combustion Engrg. Corp., N. Y.
Edge Moor Iron Co., Edge Moor.
Erie City Iron Works, Erie, Pa.
Springfield Boiler Co., Springfield, Ill.
Titusville Iron Works Co., Titusville, Pa.
Wickes Boiler Co., Saginaw.

BOOKS AND SCHOOLS
Hays Institute of Combustion, Chicago, Ill.

BREECHINGS
Connery & Co., Inc., Phila.
Littleford Bros., Cincinnati, O.
Prat-Daniel Corp., New York.

BRICK WORK
Erie City Iron Works, Erie, Pa.

BRICKS, FURNACE LINING
Norton Co., Worcester, Mass.

BRUSHES, DYNAMO AND MOTOR
Dixon Crucible Co., Jos., Jersey City, N. J.

BRUSHES, GRAPHITE
Dixon Crucible Co., Jos., Jersey City, N. J.

BUCKET ELEVATORS
Bartlett & Snow Co., The C. O., Cleveland, Ohio.
Fairfield Engrg. Co., Marion, O.
Jeffrey Mfg. Co., Columbus, O.
Link-Belt Company, Chicago.
Stephens-Adamson Mfg. Co., Aurora, Ill.

BUCKETS, CLAMSHELL
Orton Crane & Shovel Co., Chicago, Ill.

BUCKETS, COAL HANDLING
Jeffrey Mfg. Co., Columbus, O.
Orton Crane & Shovel Co., Chicago, Ill.

CAR DUMPERS
Wellman-Seaver-Morgan Co., The, Cleveland, Ohio.

CARRIERS, PIVOTED BUCKET
Bartlett & Snow Co., The C. O., Cleveland, Ohio.
Jeffrey Mfg. Co., Columbus, O.
Stephens-Adamson Mfg. Co., Aurora, Ill.

CASTINGS
Fuller Lehigh Co., Fullerton, Pa.
Neemes Fdry., Inc., Troy, N. Y.

CEMENT, ACID-PROOF
Quigley Furnace Specialties Co., Inc., New York, N. Y.

CEMENT, FURNACE
Faulkner Refractories Co., J. A., Youngstown, Ohio.
Harbison-Walker Refract. Co., Pittsburgh.
Johns-Manville Corp., New York.
Lavino and Co., E. J., Phila.,
McLeod & Henry Co., Troy, N. Y.
Norton Co., Worcester, Mass.
Refractory & Engineering Corp., New York, N. Y.

CEMENT GUNS
Cement-Gun Co., Inc., Allentown, Pa.

CEMENT, HIGH TEMPERATURE
Faulkner Refractories Co., J. A., Youngstown, Ohio.
Harbison-Walker Refract. Co., Pittsburgh, Pa.
Johns-Manville Corp., New York.
Lavino and Co., E. J., Phila.,
McLeod & Henry Co., Troy, N. Y.
Norton Co., Worcester, Mass.
Quigley Furnace Spec. Co., N. Y.
Refractory & Engineering Corp., New York, N. Y.

CEMENT, IRON
Smooth-On Mfg. Co., Jersey City.

CEMENT, REFRACTORY
Quigley Furnace Specialties Co., Inc., New York, N. Y.

CHAIN WHEELS
Babbitt Steam Specialty Co., New Bedford, Mass.

CHAINS, DRIVE
Link-Belt Company, Chicago.

CHEMICALS, WATER TREATING
National Aluminate Corp., Chicago, Ill.

CHIMNEYS
American Chimney Corp., N. Y.
Ballard, Sprague & Co., Inc., New York, N. Y.
Littleford Bros., Cincinnati, Ohio.
Prat-Daniel Corp., New York.
Rust Engrg. Co., Pittsburgh.
Springfield Boiler Co., Springfield, Ill.

CIRCUIT BREAKERS
I-T-E Circuit Breaker Co., Philadelphia, Pa.

CLEANING COMPOUND
Dearborn Chem. Co., Chicago.

COAL AND ASH-HANDLING MACHINERY
Allen-Sherman-Hoff Co., Phila
Bartlett & Snow Co., The C. O., Cleveland, Ohio.
Beaumont Co., R. H., Phila.
Detrick Co., M. H., Chicago.
Fairbanks, Morse & Co., Chicago.
Frederick Iron & Steel Co., Frederick, Md.
Jeffrey Mfg. Co., Columbus, O.
Link-Belt Co., Chicago.
Orton Crane & Shovel Co., Chicago, Ill.
Stephens-Adamson Mfg. Co., Aurora, Ill.

COAL BUNKERS, CAST IRON, CATENARY
Allen-Sherman-Hoff Co., Phila.
Beaumont Co., R. H., Phila.

COAL CARBONIZING APPARATUS
Combustion Engrg. Corp., N. Y.

COAL CRUSHERS
Bartlett & Snow Co., The C. O., Cleveland, Ohio.
Fuller Lehigh Co., Fullerton, Pa
Jeffrey Mfg. Co., Columbus, O.
Orton Crane & Shovel Co., Chicago, Ill.
Pennsylvania Crusher Co., Phila.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Strong-Scott Mfg. Co., Minneapolis, Minn.